THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. V.

No. VIII.—AUGUST, 1908.

ORIGINAL ARTICLES.

I.—On the Evidence for Desert Conditions in the British Trias.

By Professor T. G. Bonney, Sc.D., LL.D., F.R.S.

A PAPER by Mr. J. Lomas on "Desert Conditions and the Origin of the British Trias" appeared last year in the Proceedings of the Liverpool Geological Society,[1] and was reprinted, with some slight abridgement, in the November and December numbers of this Magazine. Valuable and suggestive as it is, I venture to think that its author, as is not unfrequent with enthusiastic advocates, is attempting to prove too much. I have more than once expressed my belief[2] that the pebble beds of the Bunter, perhaps also its Upper and Lower Sandstones, were deposited on a lowland by mountain-fed rivers, and think it very probable that this lowland, in consequence of its geographical position, may have been generally arid, and its temperature rather extreme, as is the case in Turkestan and parts of Persia: the occasional wind-worn sands being due to the one cause and the angular breccias to the other.[3] But I think the Keuper Marls, on the whole, aqueous rather than æolian in origin, and the Lower Keuper Sandstones, with the Waterstones, indicative of the gradual setting in of inland sea conditions. From time to time, before the salt lake attained its greatest dimensions, the wind might blow the lowland dust into dunes or carry it away from the shore till much of it settled down beneath the water, but I still think that a large part of the material, which now forms the red marl, was brought down as river mud to this magnified Dead Sea, by the streams which had formerly transported sand and pebbles.[4] In regard to this, however, we cannot at present speak dogmatically. More study is needed of the constituents of the Keuper Marl, of fluviatile, lacustrine, and even marine muds, as well as of the lighter

[1] Proc. Liverpool Geol. Soc., 1906–7, p. 172.

[2] See for instance Quart. Journ. Geol. Soc., vol. lvi (1900), p. 288.

[3] See for a fuller statement Quart. Journ. Geol. Soc., vol. lviii (1902), p. 201. [Also paper on "Wind-worn Pebbles in the British Isles," by F. A. Bather, M.A., F.G.S.: Proc. Geol. Assoc., vol. xvi (1900), pp. 396–420, pl. xi and text-figures (with numerous references to the literature of the subject).—Edit. Geol. Mag.]

[4] See for a general statement of my views Proc. Yorkshire Geol. Soc., vol. xvi (1906), pt. 1, on the origin of the British Trias.

æolian deposits, before we can determine what parts wind and water have respectively taken in making this member of the Trias. Here, however, I may remark that neither Professor Watts nor Mr. Walcot Gibson was the first[1] to observe that in the Charnwood Forest region the Keuper fills up hollows in the older rocks.

This, however, is a small matter, like all questions of priority, so I pass on to the points in regard to which I cannot wholly agree with Mr. Lomas. The following extract from his paper may serve as a summary (p. 196): "The pebble beds of the Midlands, although originally of fluviatile origin, do not exhibit the characteristics of river action. The individual pebbles show no orientation in the arrangement of their longer axes, but are wedged together in a tumbled mass as if they had dropped into their present situations by the removal of material about them. The insecurity of their positions is evidenced by the pitting which has resulted from their successive readjustments. The interspaces between the pebbles are almost free from sand, but lenticular seams of sand occur, which may have been protected from removal by wind, when the pebbles formed a continuous covering. There are places in our own district where it does not appear that concentration took place, and the sand with pebbles marking the situations of temporary streams still persist as originally laid down."

Of these points I will take the pitting first, since it needs only a brief notice. As the depressions, though generally very shallow on hard quartzites, may be almost a quarter of an inch deep, and correspondingly large on mudstones, they must have been rather slowly formed (compare those on the pebbles in the similar but indurated deposits of the Swiss nagelfluhe). Hence I should regard them as more probably indicative of a long and continuous pressure (often associated with solution[2]) than of one successively applied to new parts. Moreover, the readjustments demanded by Mr. Lomas must be brought about by the withdrawal of material from below, for we cannot suppose the impression to have been made during the brief time when the pebbles in any one layer were exposed (in simple contact, without an overlying weight) to the action of the wind. Such withdrawal could perhaps be effected by subterranean water washing away the finer material from some underlying gravel, but, as will be seen, I have found no real evidence that this has actually occurred, and it would give no help to Mr. Lomas' hypothesis.

The other points may best be answered by a brief summary of observations made last December at three places on Cannock Chase, in order to verify my recollections of past work,[3] and study some sections in the light of this new interpretation. As my time was necessarily short, I selected three places sufficiently far apart to be fairly representative of the whole district. One was at the top of Stye Cop, another near Baland's Pool (by the road from Rugeley to Hednesford), and the third on the Satnall Hills. The first was about

[1] Lomas, *op. supra*, p. 184, et. 193. See Hill & Bonney, Quart. Journ. Geol. Soc., vol. xxxiii (1877), p. 754. But it was also noticed by earlier writers.

[2] See T. Mellard Reade, Geol. Mag., 1895, p. 311, and Plate XI.

[3] Since 1895 I have but seldom visited this moorland.

1¾ miles from the second and nearly 300 feet vertically above it,[1] and both of them were about five miles from the third. The following is an abstract of my notes:—

(1) Near the top of Style Cop. The pit is on two levels. The face of the upper one, about 7 feet high,[2] showed a mass of pebbles embedded in sand, generally uniform, but with local indications of false-bedding and one or two horizontal streaks of sand. That of the lower pit (practically continuing the other and about the same vertical height) displayed alternating bands of pebbles (the thickest, with an intermittent sand-parting, being about 3 ft. 6 in.) and false-bedded sands with occasional stones. The pebbles throughout range up to about 4 inches in diameter, but the majority are considerably below this. The flatter specimens usually lie with their longer axes horizontal. Commonly there is plenty of interstitial sand, amounting perhaps to one-third of the whole mass, the larger pebbles as a rule not touching one another.

(2) Pits near Baland's Pool: (*a*) Near the Waterworks. Section about 18 feet in height; practically continuous gravel, sand-bands being almost absent: stones varying from small to large, the latter in a few cases exceeding 6 inches in diameter. False-bedding of coarse and fine gravel, or 'pockets,' two or three feet across, of small stones, with little interstitial sand, occur in places, but the latter are quite local, and, except in them, there is plenty of a rather muddy-looking sand between the stones.—(*b*) By the side of the Rugeley and Cannock railway. A cutting, perhaps 200 yards from end to end, and over 40 feet in the highest part, its base being concealed by talus. At the top is a continuous mass of pebbly gravel, about 5 yards thick; beneath it, for about 8 yards, is a gravel similar, but interrupted by sand-bands, sometimes extending horizontally for dozens of yards and attaining a maximum thickness of about 4 feet. There is plenty of sand among the pebbles. The whole mass has a conspicuous 'horizontal' aspect, and very closely resembles some of the old river gravels in the outer zones of the Alps.

(3) Pits on Satnall Hills, northern side of the Rugeley and Stafford road: (*a*) Nevett's pit.[3] Vertical section at highest point more than 30 feet. At the top is a thick bed of gravel, with occasional thin bands of sand. Below that is a well-defined band of the latter (maximum thickness about half a yard). Then come about 5 feet of well-bedded, rather sandy gravel, resting on another sand-band, nearly 2 feet in greatest thickness, and under it about 7 feet of gravel (pebbles as a rule under 3 inches), generally conspicuously false-bedded, but less so in the last foot, after which another thick bed of gravel, with larger pebbles and more or less definitely horizontal

[1] The height of Style Cop is 721 feet (the pit is slightly lower). The road by the Waterworks, a few feet below the second pit, is 418 feet above sea-level. I should estimate the altitude of the Satnall Hills pits to be about the same.

[2] The measurements throughout these notes are only estimates. It would not always have been possible to apply a tape, and as the weather was cold it was not worth risking a chill for the sake of a useless precision.

[3] In this pit my nephew, (now) Lieut. F. G. C. Wethered, found that fossiliferous pieces of Carboniferous Limestone were less rare than usual.

layers of sand, extends to the pit floor.[1] This is varied occasionally by irregular seams of fine gravel (stones not bigger than a walnut) or by lenticular streaks of sand, not exceeding a few inches in thickness. Ovoid pebbles generally lie with their longest axis horizontal, but in false-bedded parts this follows the dip. Plenty of sand is usually present in the gravel.— *b*) Pit nearer to the enclosure of Shugborough Park. The beds exposed (probably just underlying those seen in the other pit) afford a section about 18 feet at thickest. It will suffice to say that we find in this a gravel, like that in the other pit, with long thin lenticular beds of sand, horizontally intercalated. Here also the longer axes of the stones are horizontal, sometimes conspicuously so; the whole mass, like that in the other sections, suggesting a fluviatile origin.

Several times, while making the above observations, I examined the sand with a strong lens, and found my recollections to be correct,[2] viz., that, while rounded grains occasionally occur, the majority are more or less angular: hence material, presumably water-borne, dominates considerably over wind-borne. Thus, while I do not deny that the conditions in the British lowlands during Triassic times resembled those of a desert region more nearly than they do at present, I think that the Liverpool district, to which Mr. Lomas's observations refer, must be a rather exceptional one. Unfortunately, my acquaintance with this is slight, but my studies of Triassic deposits, both in Central Staffordshire and in other parts of England, have led me to believe that, even in Keuper times, water played a larger part than wind in their formation.

P.S.—This paper was written early in the year, but as I was leaving England for some weeks in the spring it was kept back, because I wished to add a few words on some pebbles which I find not previously noticed in the Bunter. They occurred in the Style Cop pit and in that near the Waterworks. In each case they were restricted in vertical range, not at all common, the longest diameter generally under two inches, flattish, but fairly well rounded, less than the ordinary weight, damp, soft, and dark-coloured (becoming paler when dry), with an amber-brown streak. At the time I thought they might be a rotten cannel, or at any rate rather rich in some hydrocarbon. On examining under the microscope, after my return to Cambridge, the powder from one of them, I found no traces of organic structure, though some translucent brown particles suggested the presence of a bituminous constituent among the ordinary mud-like material. But Professor Seward, who kindly made a more complete investigation, informed me that he could not detect any traces of plant tissue, and Mr. A. Hutchinson, University Demonstrator in Mineralogy, to whom I am indebted for examining a fragment during my absence, writes: "It does not contain carbon, but appears rather to have resulted from the oxidation of some metallic ore. In the main it consists of hydrated iron oxide together with a certain amount

[1] A few of the largest stones even exceed 6 inches in diameter.

[2] See Quart. Journ. Geol. Soc., vol. lvi (1900), p. 288; Proc. Liverpool Geol. Soc., 1901–2, pp. 230–233.

of silica and a fair quantity of oxide of manganese. I have not found any certain indication of arsenic, but small quantities of antimony are present, and I have detected a trace of copper." Possibly, then, these pebbles may have been derived from the 'blackband' (beds impregnated with iron-carbonate) of the Coal-measures, much of the metal having been removed and the rest altered to limonite by the action of water.

II.—The Red Zone in the Basaltic Series of the County of Antrim.

By Grenville A. J. Cole, F.G.S., Director of the Geological Survey of Ireland.

ONE of the most beautiful features at the Giants' Causeway, from an artistic as well as a geological point of view, is the broad red zone that divides the Lower from the Upper Basalts. As is well known, this zone of lithomarge, bole, and laterite is remarkably persistent in north-eastern Ireland, and represents an interval of Eocene time when volcanic activity was lessened and when the basalts ceased to appear at the surface. At the same time, however, sporadic eruptions of rhyolite occurred, and some of the cones of acid lava supplied material for an interbasaltic conglomerate of rhyolite pebbles, which was discovered several years ago by Mr. A. McHenry near Glenarm.[1]

The occurrence of leaf-beds, lignites, pisolitic iron-ores, and pale bauxitic muds on this horizon has led to the prevalent opinion that the whole red zone and the associated rocks of lighter colour are of detrital origin. Portlock[2] seems to have laid the foundation for this view in 1843, when he regarded the amygdaloidal basalt as an alteration-product derived from a compacter form, and suggested that some of the amygdaloids were poured out "rather in the state of volcanic mud than of lava." But at the same time he regarded the bole as resulting from the induration of amygdaloids that "have been decomposed on the surface," and pointed out the intimate association of the hard and soft rocks in the uppermost portion of the Lower Basalts.

From Portlock's time onward, the tendency has been to emphasise the appearances of stratification and fragmental structure along this zone; and John Kelly,[3] in 1869, in his remarkable paper on the geology of Antrim, refers to the deposits as "volcanic ashes thrown up in the eruption, and disseminated in the water, making literally a red sea." On the other hand, Messrs. Tate and Holden,[4] almost in the same year, maintained that the lithomarge and bole are but decomposed basalts, and traced the passage from unaltered blocks into the soft rock round about them. They held that the basalt was poured out under water, and rotted there, so as to produce the red zone, and went so far as to

[1] See Sir A. Geikie, Anniversary Address, Quart. Journ. Geol. Soc. London, vol. xlviii (1892), Proc., p. 168; and McHenry, Geol. Mag., 1895, p. 280.

[2] "Report on Geology of Londonderry, etc.," Dublin, 1843, pp. 145–6.

[3] "On the Geology of the County of Antrim, with parts of the adjacent Counties," Proc. R. Irish Acad., vol. x, p. 307.

[4] "On the Iron-ores associated with the Basalts of the North-East of Ireland," Quart. Journ. Geol. Soc. Lond., vol. xxvi (1870), pp. 155 and 158.

urge that the pisolitic layer was produced by contact-action proceeding from the subsequent Upper Basalts. This suggestion may have affected the reception accorded to their views on the decomposition of basalt *in sitâ*; and the larger ovoid blocks of basalt embedded in the lithomarge came to be treated as "bombs of rounded and exfoliating basalt,"[1] while the series generally was spoken of[2] as "beds of tuff or ash, together with bole, lithomarge, and pisolitic iron ore, which always occur below the Upper Basalt." Much of this material was believed to have accumulated in lakes.[3]

The appearance of bedding in the 'pavement'—a name for the variegated ferruginous rock underlying the rich pisolitic ore—is certainly clear, and seems highly conclusive in hand-specimens. But successive visits to the famous sections at the Giants' Causeway, which are now rendered so accessible by the railed and carefully constructed path, have convinced me that there, at any rate, tuffs and ashes played no part in the red zone. The neighbourhood of true ash and tuff, splendidly displayed at Carrick-a-rede, served to prevent hasty generalisation; and I confess I was hardly prepared, when arranging for a general examination of the interbasaltic beds by the staff of the Geological Survey of Ireland, for the way in which section after section declined to show us more than is revealed along the cliff-path at the Giants' Causeway.

In that typical locality every kind of 'red rock' that is found in what has been claimed as a stratified interbasaltic series occurs in intimate association with unmistakable basaltic lava. Red bole, without a trace of original structure, is found in, and not merely on the surface of, the basalt. At times this bole is pisolitic, showing that the structure most readily conceded to be of lacustrine origin may also arise by concretion in a decomposing mass. The jointing of the basalt is continuous with that of the overlying jointed lithomarge, and the 'onion structure' between the main joints of the latter is clearly a relic of that which arose from contraction in the basalt. This onion structure occurs in very fresh basalt near Carrick-a-rede, and is evidently only emphasised, and not originated, by decomposition. The lithomarge, of strange purple-grey and violet tints, now and then retains pseudomorphs of the felspars of the original basalt, and consequently traces of the mesh-structure of the basaltic ground. Unreddened iron-ores remain as black specks; but this type of rock passes into one recognisable only in the field as the product of decay of basalt. The great 'bombs' of residual lava are surrounded by zones of red and brown and orange, which are the same as those that stripe the lithomarge and 'pavement,' and thus give it an appearance of lamination. At the Causeway such colour-bands run in various directions, and often a concentric group of them alone represents the site of a 'bomb' that has completely decomposed.

The alleged 'bombs' can be nothing else than unweathered cores of basalt, in a zone of deep lateritic decomposition, which spread

[1] Mem. Geol. Surv. to Sheet 14 (1886), pp. 20 and 22. Cf. Sir A. Geikie, "Ancient Volcanoes of Great Britain," 1897, vol. ii, p. 204.

[2] Mem. Geol. Surv. to Sheets 7 and 8.

[3] Ibid. to Sheets 21, 28, and 29, p. 29.

downwards from the surface of the flow. Every stage can be traced, from tough dark ovoid masses to those that have left a crumbling greenish residue, or have vanished altogether in a sort of sunset glory of brilliant stripes and bars. If anyone, after a careful visit to the Causeway area, remains unconvinced of this, an inspection of the shore at Brown's Bay, Islandmagee, a locality probably well known to Messrs. Tate and Holden, will assure him of the correctness of the views of those authors, so far as the general origin of the red zone is concerned.

The whole matter of basaltic decomposition has, of course, received new elucidation in the last few years from the studies on the production of laterite in tropical climates, which have been published in the Geological Magazine and elsewhere. Basalt, like almost any rock containing salts of iron, will, under tropical conditions, rot downwards from an ordinary terrestrial surface, giving rise to red aluminous iron-ores. Seasonal rainfall doubtless helps this action; but it naturally goes on subaerially, and not, as Messrs. Tate and Holden suggested, under cover of permeating waters. There is now no difficulty in realising the formation in Eocene times of ten or forty feet or more of red material, rich in iron and alumina and relatively poor in silica, during the resting-stage in the volcanic activity of our islands. The comparatively thin layers of pisolitic iron-ore on the surface of the red zone may be conceived as formed from time to time in pools that gathered during the rainy seasons. The evidence for the existence of a warm climate in the Eocene period over the area of the British Isles is considerably strengthened by the presence of the red zone in Northern Ireland.

In 1895[1] I suggested that the pale bauxites of the county of Antrim were derived from rhyolitic material. They appear typically above the pisolitic iron-ore, thus effectually disposing of the idea that the concretionary structure in the latter is due to metamorphism by the Upper Basalt. John Kelly[2] acutely noted "clear quartz crystals . . . with double pyramids complete" in the red zone at the Bull's Eye Waterfall, some miles south of Glenarm. Mr. A. McHenry has now (1908) observed these crystals and other quartz fragments, which are clearly detrital, over a wide area between Glenarm and Straid Hill; they sometimes occur in a reddened bed, sometimes in typical pale bauxite. The recent work of the Geological Survey tends strongly to connect the pale bauxites with the decay of local rhyolite of the Tardree type: and in many places we have to conceive the formation of a sandy deposit, blown from crumbling rhyolitic surfaces, and spread out as a comparatively thin layer over the lateritic Lower Basalt. The parallel between this deposit and the sands accumulated by wind on the surface of the basalts in the bush-land of the Central Zambesi is one that appeals to the geologist, as affording a picture of our own area in early Cainozoic times.

The present paper, urging that the red zone was essentially formed

[1] "The Rhyolites of the County of Antrim; with a note on Bauxite," Trans. R. Dublin Soc., vol. vi, p. 198.

[2] Op. cit., Proc. R. I. Acad., vol. x (1869), p. 303.

by the decay of solid basalt *in sitû*, and that the so-called 'volcanic bombs' in reality afford the best evidence of this decay, is, after all, but an echo from the thunders of the old Neptunist controversy. Long before Messrs. Tate and Holden wrote, the Rev. Dr. W. Richardson, a determined opponent of the Vulcanists, stated, in a memoir sent to the Royal Society of Edinburgh, that the red strata had "been once pure basalt." This memoir does not seem to have been published, but the argument is emphasised in a paper printed in 1803[1] and in several subsequent publications. The most important of these is Richardson's "Letter on Zeolite and Ochre,"[2] in which he rightly denies that the ochres are "*pozzolana* or *tufo*," and quotes St. Fond in support of his opinion. On p. 14 he says, "we find this ochreous substance in its natural situation in every intermediate stage between sound blue basalt and ochre red as minium; and we see that the passage from one extreme to the other is by shades perfectly insensible." He does not like to say whether the change into ochre, the cause of which he does not specify, has now come to an end or is still in progress.

Berger and Conybeare[3] describe the bole as occurring in beds, but do not commit themselves as to its mode of origin. It is fairly clear that Richardson's uncompromising opposition to Hutton's theory of terrestrial changes, and his denial of the existence of ash-beds in association with true basalts, led to the rejection of his views on the relations of the red zone of North-East Ireland. These views, however, prove to be far better founded than those maintained a century later by the successors of the Vulcanist school.

III.—A remarkable instance of Rock Differentiation.

By Harford J. Lowe, F.G.S.

(PLATE XIII.)

UPON Sheet 339 (Devonshire) of the new Geological Survey maps, one instance out of the very numerous outcrops of igneous rocks thereon indicated proves to be of unusual interest by reason of its peculiar constitutional modifications in different parts of the same mass. The rock in question occurs about four and a quarter miles 15° north of west from Newton Abbot, near to the hamlet of Bickington, within the limits of a farm named Lurcombe. It is an intrusive, amidst the shales and grits of the Culm, occurring almost on the junction-line between that series and the Devonian, whose massive limestones and volcanics dominate it in elevation within a quarter of a mile on the south-east.

[1] "Inquiry into the consistency of Dr. Hutton's theory, etc.," Trans. R. Irish Acad., vol. ix (1803), p. 458. See also "On the alterations . . . in the Structure of Rocks, on the surface of the basaltic Country in the counties of Derry and Antrim," Phil. Trans. Roy. Soc. (1808), pp. 195 and 200.

[2] Appendix I, p. 11, in Dubourdieu, "Statistical Survey of the County of Antrim," Dublin, 1812.

[3] "On the Geological Features of the North-Eastern Counties of Ireland," Trans. Geol. Soc. London, vol. iii (1816), p. 186.

A small stream with south-east course has cut a narrow valley through the softer Culm material contiguous to the igneous rock on the west, and sweeping round the mass to form nearly a right angle continues its course in a north-east direction into the Bovey depression. Thus the igneous mass is cut out of its enveloping sedimentaries on both the west and south sides, presenting precipitous slopes in those directions. The top and slopes of the rock are grass-covered, but at the shoulder two or three bare masses protrude through the sward, and a small quarry has been worked in it at a lower elevation to get road-metal for the farm tracks.

The position being near to the edge of the Bovey basin the rocks decline eastward, dipping towards and beneath the Bovey deposits, so that the intrusive, taking the inclination of the invaded strata, becomes immediately buried therein in that direction. In a hollow or combe, however, of the adjoining farm called Stancombe, an adit has been driven in connection with some unsuccessful mineral researches, and among the débris some pieces of a similar igneous rock occur showing that the intrusive had been reached in the excavation and is continuous in that direction. The declivity at the bend of the stream measures some 120 to 140 feet in vertical height, which would also appear to indicate the thickness of the intrusive rock.

The first specimens of the rock obtained were not found *in situ*, but from masses used to support a hedge bank along the shoulder of the hill in the usual Devonshire way. Some of these blocks showed a nodular structure, were much weathered, and required considerable labour to obtain a piece sufficiently fresh to be of service for microscopical examination. Regarded as another variety of the diabase so common in the neighbourhood, a surprise was in store, when from a number of sections obtained one proved to be entirely different from any of the others. This section from the Lurcombe specimen contained no augite, but in place of it original brown hornblende. My surprise and interest led me to trouble Dr. Teall in respect to my interpretation of the rock as having the composition of a camptonite, which he kindly confirmed. Several subsequent visits have led to the discovery that the rock is of still further interest by giving examples in micro-sections of not only hornblende as the ferro-magnesian mineral, but of both hornblende and augite in idiomorphic form; of augite predominating with hornblende as a growth upon it; and another variation with augite alone having the ophitic habit. These peculiar variations in constitution in the same igneous mass are sufficiently remarkable to receive special notice, if indeed they do not characterize it as a unique instance of differentiation in mass without any evidence of dynamic deformation.

The sections described in the following detail occur in descending order from the higher to the lower elevation of the rock-mass as they could be obtained *in situ*, and represent the varying constitution from the upper to the lowest parts of the intrusion as near as can be ascertained. They are classed as I, II, III, and IV, to distinguish the grades of (i) hornblende alone, (ii) hornblende and augite, (iii) augite predominant, and (iv) augite alone.

Grade I is a coarsely grained rock, weathering a rusty brown, with

long dull reddish-brown crystals, some attaining a length of 15 mm. Fresher rock in hand-specimen is of greyish-blue colour. A micro-section displays hornblende and felspar as the chief constituents of the rock, with iron-ores and apatite as accessories. The secondary minerals comprise chlorite, calcite, mica, and leucoxene. The hornblende is of a rich brown colour, and is in well-developed crystals of varying sizes, showing crystal faces and cleavages very perfectly. Constitutionally, however, the hornblende has much suffered by decay. The crystals are frequently traced with chlorite, and are met with in all stages of chlorite transformation, even to a complete paramorph of the secondary mineral, with the original crystal outlines remaining perfect. The pleochroism of the hornblende is very pronounced from a very pale brown to a rich red brown, with birefringence colours ranging from bright yellow, golden brown, to a greenish-red lustre in moderately thick sections. Twinning is seen occasionally in the better preserved crystals.

The felspar presents anomalistic relations. Some appears in irregular plates with very indefinite boundaries; part in lath shapes, in sheaf or fan arrangement, with still smaller forms in curved and feathery microliths. The lath-shaped felspars are frequently attached in an irregular way to the phenocrysts, giving them an appearance of frayed out edges, not always in crystalline continuity. They sometimes, however, occur in sheaves or single laths in spaces filled with a groundmass material, which is nearly isotropic. This interstitial matter is mainly resolved by higher power into minutely crystalline material, probably of a felspathic nature, amidst which the curved and feathery shapes are intermediate in size to the laths. Here also occur occasional small imperfect hornblendes, partially decomposed coloured mica flakes, as well as chlorite and calcite granules. The larger felspar plates which frequently enclose the hornblende are much altered, the secondary product therefrom appearing as brilliantly polarizing flecks of colourless mica. These being formed along the cleavage planes, their consequent parallelism permits series to extinguish together. Occasionally a cleavage trace may be seen in these larger felspars, indicating simple twinning, but the evidence of polysynthetic albite twinning is too rare and faint to deem it a habit in the development of these phenocrysts. Marginal differences, noticeable in the partial extinction, declare zonal variation in original constitution. The extinction obtainable in the larger felspars is most often within very small angular distance of available lines of measurement, occasionally identical therewith; while in the laths extinction takes place almost invariably with the cross line parallel to the long axis of the crystal. These indications correspond to those of a plagioclase of varying constitution, related to the acid end of the series, oligoclase and andesine, the lath crystals being probably of a more acid character than the larger felspars.

Of secondary minerals, chlorite is the most abundant in its common form of strings of fan-like concretions, and calcite is common in both compact and granular condition. Pyrites is sometimes present, though rare, and ilmenite is a sparingly common accessory, often assuming the semi-translucent condition, indicating its change to leucoxene.

Apatite in long prisms of varying stoutness is sometimes abundant, in other instances rare. The constitution of this variety of the Lurcombe rock-mass corresponds with that called camptonite (Rosenbusch) or hornblende lamprophyre (Harker).

The varieties of the rock classed as grades II and III are those in which augite is associated with the hornblende. In grade II both these minerals are found in idiomorphic form, sometimes in about equal proportions, though in most instances obtained the augite predominates, and these merge into grade III, where very little hornblende is met with, and that almost entirely attached peripherally to the augite, a way in which it also occurs in grade II.

In these varieties the hornblende is exactly similar to that of grade I, though not in such well-developed crystals, and varies in relative quantity to the augite from a slightly preponderating proportion to insignificant attachments to the augite, with occasional patches contained within the augite crystals. The augite is in well-formed idiomorphic crystals giving varying flesh tints with rotation, and brilliant double-refringence colours, showing occasionally hour-glass structure and other zonal markings. Twinning also occurs. This mineral is in a better state of preservation generally than the hornblende, though chloritization has frequently taken place in patches and lines within the crystals, with the usual accompaniment of calcite, its related decomposition product.

The felspar diminishes in relative amounts with the increase and predominance of the augite. It however maintains the characteristics already described, there being still platy, lath-shaped, and minute curved forms; the larger irregularly shaped plates are much micaized and occasionally have partial surroundings of fresher material and of more acid constitution. In these two grades of the rock a difference is noticeable frequently, in the feebly translucent interstitial material before mentioned. Clear spaces are to be seen containing an almost isotropic mineral, detected by faint lines of cleavage in the shadowy illumination got by rotation. This additional secondary mineral was doubtfully considered to be analcite, but by Dr. Flett's kindly assistance a certainty in the matter has been established. In no instance has the analcite definite boundaries, but it merges into the surrounding material, the apparent bye-products of its formation. Calcite is always associated with the analcite bordering and veining it, and chlorite is occasionally seen partially surrounding it. There is also an instance of analcite with its usual border and veins of calcite grains occurring within an augite crystal.

Besides the mica which mosaics the felspar plates some small crystals of a coloured variety are occasionally seen in the interstitial material. The accessories are the same as noted in grade I. These varieties of the rock-mass, distinguished as grades II and III, thus have a mineral constitution to which petrographical nomenclature has ascribed the term Teschenites.

The Lurcombe mass presents still another variation, which follows the direction of differentiation indicated by those already described. This variety, distinguished as grade IV, contains no hornblende, the only original ferro-magnesian being augite, which assumes a sub-ophitic

relation towards the larger felspars. In this instance the augite does not appear in idiomorphic form, but is seen in plates with irregular boundaries surrounding and enclosing some of the felspar; while the opposite change has taken place in the felspar, it occurring in crystal form, though of only small dimensions. In this grade the interstitial matter is mainly analcite with calcite and chlorite, the two latter secondary products occurring also in the decomposing augite. In this section analcite is seen enclosing lath felspars, and some glassy clear grains, with apparent cleavage traces, may be secondary felspar. Ilmenite and apatite continue as accessories.

Grade IV is thus an instance of a rock, with the original composition of a dolerite, that has undergone the changes which constitute it a diabase, except for the presence of the mineral analcite. This additional mineral presumably will necessitate the variety being given either a specific name or a differentiating prenomen such as analcite-diabase or augite-teschenite.

Pieces of the same intrusive obtained from the output of the mining operations on Stancombe farm show a rock more altered than any from the Lurcombe exposure. This might be expected, as the fact of a metalliferous vein being sought for there arose from alterations in the appearance of the surface material, due doubtless to some local changes or disturbances that were misinterpreted by the miners. A hand-specimen of the igneous rock obtained from the mining débris shows long grey crystals and spots of white in a dark-grey base. Sections present neither hornblende nor augite. Both have entirely disappeared and their places taken by paramorphs of an opaque fibrous mineral threaded occasionally with chlorite. Chlorite and calcite occur in other parts of the sections, as well as fairly well-formed plates of a coloured mica, occurring sporadically, and most frequently not fresh but considerably chloritized. The felspars are in much the same condition as before described, and analcite has been detected in only one section. The accessories ilmenite and apatite do not appear to have suffered any change.

Considering the varieties of rock described above as the products of the same mass and of a single intrusion, the association of such differences is so unusual that no general or current explanation of rock differentiation seems to apply in this instance. As far as my acquaintance with the literature of igneous rocks extends, I am aware of no similar or analogous case, and in endeavouring to find a solution for what appears an extremely rare, if not unique, occurrence, I can suggest no explanation which seems to so fully and simply account for the facts as by considering the variations due to a differentiation of magmatic constitution by gravitation. It has been remarked that there is no evidence in hand-specimen or section of dynamic deformation within any part of the mass, and though not far from the granite it is outside the marginal area influenced thereby. The camptonite variety occurs at the top or upper side of the intrusion, and the evidence points to the decrease and even disappearance of the hornblende as the lower part of the mass is reached. This suggests the following explanation:—Assume a homogeneous magma to be intruded between horizontal strata. It is so constituted that the first important mineral

to crystallize out is augite. This would take place earliest in the upper part of the magma, which would presumably be the region first reduced to crystallizing condition. The augite crystals thus generated, having a specific gravity higher than their liquid matrix, would sink therein until the consistency of the matrix prevented further gravitational progress. Such movement taking place would render a zone in the upper part of the magma free of augite, and cause some slight upward flow of the more liquid matrix. This augite-free area would contain eutectic material differing somewhat in constitution to that from which the augite arose, and it may be inferred from the circumstances that the differentiation was such as to superinduce the formation of hornblende during the final stages of consolidation. Such possibilities being granted, it is obvious that less favourable conditions for the formation of hornblende would prevail deeper in the mass, and its mode of occurrence there as well as absence in the lowest parts is consistent with the above hypothesis.

In seeking for accounts of rocks similar to those under consideration, in order to make comparisons therewith, I have been particularly interested in a description by Messrs. R. Campbell, M.A., B.Sc., and Andrew G. Stenhouse, F.G.S., of the "Geology of Inchcolm."[1] On this island there is a sill composed of picrite and teschenites, the latter forming the upper and lower portions of the sill. There, as at Lurcombe, the teschenite varies considerably in respect to the relative quantities of hornblende and augite appearing together, and the varieties are distinguished as augite or hornblende types as either mineral may predominate. The hornblende type preponderates on the upper side of the sill, and the augite type, the hornblende occurring with it, on the lower side. Their mode of occurrence in relation to the picrite is that of 'merging' as well as that of 'banding.' There is "a well-developed 'rolling over' of hornblende teschenite and augite teschenite along with the picrite—which, in a remarkable way, is suggestive of flow structure," as explained by Mr. Harker for the Skye peridotites, a "result of fluxion in a magma which was heterogeneous at the time of intrusion."[2] A similar suggestion has been made to account for the remarkable acid and basic banding in the 'granulitic' of the Lizard area.[3] But there can be no question of the small Lurcombe mass being other than a single flow of a homogeneous magma differentiated *in situ*. The teschenites of Inchcolm merge into each other in respect to the relative amounts of augite and hornblende, but there do not appear to be any portions of that rock quite free from either augite or hornblende.

The analcite of the Inchcolm teschenites is a prominent feature, occurring apparently in larger quantity relative to mass and crystal development than is found in the rock described above. It is considered by the authors to be an original mineral. I have regarded the analcite of the Lurcombe rock, which is quite subordinate in quantity, as a secondary mineral. This has been suggested by its non-appearance

[1] Transactions of Edinburgh Geol. Soc., vol. ix, pt. 2, 1908.

[2] Tertiary Igneous Rocks of Skye: Mem. Geol. Survey, p. 75, p. 123, 1904, and op. cit.

[3] Transactions of Royal Geol. Soc. of Cornwall, vol. xii, pt. 6, p. 440, 1900.

in the camptonite variety, and by its only occasionally occurring in place of the so-called interstitial material of grades II and III, as though only a partial change of that material into analcite had taken place. It is considered to be a derivative from felspathic matter as represented by Van Hise, though all the appearances do not accord with that supposition: for lath felspars can be detected buried in the analcite substance, and one instance is met with of analcite occurring within a crystal of augite. It is interesting to note, in reference to the relation of the analcite to the mass, that in the Inchcolm teschenites it is described as "filling up the spaces between the other minerals as if it were playing the part of groundmass."[1]

It is an interesting coincidence to find that both the Inchcolm and Lurcombe intrusions, which appear to be nearly related in constitution, should also belong to the same geologic age, the Culm being of early Carboniferous formation. Now if it could be shown that the analcite of the Lurcombe mass is an original mineral, it would give to the whole series of rock variations another bond of relationship. They would then be considered as gradations in teschenite types and composition. The camptonite variety could be regarded, unless disproved by analysis, as a purely hornblende teschenite with material of analcite constitution, but of imperfect crystalline development, the same material showing better crystal form in the true teschenites of grades II and III, and appearing in still better condition in the purely-augite variety of grade IV. If, however, such a probable relationship between the varieties was determined, the remarkable sequence of changes and perfect gradations met with in the rock-mass would demand some such hypothesis as gravitational differentiation to account for its exceptional condition.

EXPLANATION OF PLATE XIII.

Fig. 1.—Grade I. Parts of three hornblende crystals on N.E., S., and S.W. borders. Lath and micro-felspars in intervening cloudy groundmass. The light patch on N.N.E. border is a portion of a felspar plate which partly encloses the larger hornblende-needles of apatite and a black spot of pyrites S.E. × 25 diameters.

" 2.—Grade II. Hornblende idiomorphic and attached to augite. Groundmass of felspars, chlorite, and grains of calcite. Hornblende in dark shade. In top right-hand quarter augite bordered and terminated by hornblende. Light spots in crystals chlorite. Black pointed patch S.S.W. of ilmenite. × 25 diameters.

" 3.—Grade III. Augite with interstitial and peripheral hornblende. H. in dark shade. Light patch at bottom chlorite, with calcite immediately above it. × 25 diameters.

" 4.—Grade IV. Augite (in dark shade) ophitic to felspars. Clearest spots chlorite. × 50 diameters.

" 5.—Amygdule in a crystal of augite. The bar of white is analcite bordered and veined by calcite grains. The augite is much decomposed into calcite and chlorite, giving dark shades. The lightest patches are fresh augite. A part of a fringe of hornblende is seen at the bottom of the figure where the boundary of the crystal is nearly reached. × 50 diameters.

" 6.—Felspar in sheaves of laths or skeleton form. All of dark shade is brown hornblende. Lightest patches calcite. Some of groundmass chlorite. A long needle of apatite to right. × 50 diameters.

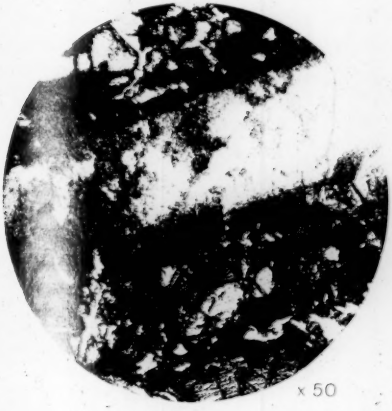
[1] Op. cit., p. 127.

1 x 25

x 25 2

3 x 25

x 50 4



x 50

x 50 6

Bemrose, Collo., Derby.

...CK SECTIONS FROM LURCOMBE, NEAR BICKINGTON, NEWTON ABBOT, DEVON

IV.—On a New Species of *Pollicipes* from the Inferior Oolite of the Cotteswold Hills.

By L. Richardson, F.G.S.

FOUR species of *Pollicipes* have been recorded from the Rhætic and Lower Jurassic Rocks of Great Britain.

1.—*Pollicipes rhaticus*, Moore. *Pteria-contorta*-Zone. Rhætic [Rhætian]. Hapsford Mills, Vallis Vale, near Frome, Somerset. Quart. Journ. Geol. Soc., vol. xvii (1861), p. 512, and pl. xvi, fig. 30.

2.—*Pollicipes rhomboidalis*, Moore. "Lias [Hettangian] at Ewenny and at Langan, Glamorganshire." The type-specimen came from the Sutton Stone [Hettangian] of Shepton Mallet, Somerset. Quart. Journ. Geol. Soc., vol. xxii (1867), p. 530, and pl. xvi, fig. 31.

3.—*Pollicipes alatus*, Tate. "Zone of *A. angulatus*." Lower Lias [Hettangian]. Island Magee, Antrim. Trans. Belfast Nat. F.C. (1870), p. 23, and pl. i, fig. 6.

4.—*Pollicipes oolithicus*, J. Buckman. Stonesfield Slate, Great Oolite [Bathonian]. Eyeford, near Cheltenham. "Outline of the Geology of the Neighbourhood of Cheltenham," by Sir R. I. Murchison, 2nd ed., by H. E. Strickland and James Buckman (1844, Cheltenham; 1845, London), p. 95, and pl. iii, fig. 7.

A fifth species has now to be added:

5.—*Pollicipes aalensis*, L. Richardson, sp. nov. Lower Limestone, Inferior Oolite (Aalenian). Well House, Haresfield Hill, near Gloucester.

The specimen was found by Miss H. M. Hutton, of Harescombe, in a small section near the Well House on the northern slope of Haresfield Hill, whence she has also procured a large number of specimens of a pentacrinite.

Examples of the plates of the capitula of *Pollicipes* are none too common in the Rhætic, Lower Lias, or Inferior Oolite rocks of Great Britain. Charles Moore has recorded that they are not infrequent in a clay-bed of Rhætic age, which rests unconformably upon the Carboniferous Limestone at the Hapsford-Mills section in Vallis Vale, near Frome, but that is the only locality I know of in these Isles where they have been found in the Rhætic.

Charles Moore has also obtained specimens of a species, which he called *Pollicipes rhomboidalis*, from the Lias of Glamorganshire and from the equivalent beds near Shepton Mallet.

Ralph Tate obtained another species from beds of about the same date (Hettangian) at the Island Magee, and named it *Pollicipes alatus*. I have found several examples of plates belonging to a species inseparable from this one in the Lias of *oxynoti-armati* hemera that was exposed when excavations were being made for a new gas-holder at the Gloucester Gas Works.

To represent the Inferior Oolite form there is only the portion of the tergum described below; but it is very distinctive, and leaves no room for doubt about its zoologic relations.

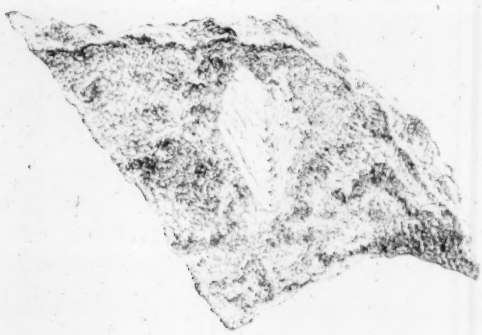
In the Stonesfield Slate of Eyeford, near Cheltenham, and Stonesfield,

near Blenheim, the plates of *Pollicipes oolithicus*, scuta, terga, and carinæ—particularly the scuta—are relatively quite common, and are to be found in most local collections that were made from forty to sixty years ago.

The Stonesfield Slate has been worked principally at three localities—Stonesfield, Eyeford, and Sevenhampton Common, near Cheltenham. At Stonesfield there is now (1908) but one pit in work, and only two men engaged in making the slates that were formerly in such demand. At Eyeford the industry is still carried on, not so actively as previously, but the industry has not decayed to the same extent as at Stonesfield. At Sevenhampton Common all the pits are closed down, but one—in a field at the south-eastern end of the common—was open until the last two years.

SUBCLASS EUCRUSTACEA.
SUPER-ORDER CIRRIPEDIA.
ORDER THORACICA.
FAMILY LEPADIDÆ.

POLLICIPES AALENSIS, Richardson, sp. nov. (Figure.)



Pollicipes aalensis, Richardson, sp. nov.

Type-locality.—Well House, Haresfield Hill, near Gloucester.

Horizon.—Lower Limestone: Aalenian.

Homera.—*Murchisonæ*.

Collection.—Miss H. M. Hutton, Harescombe, near Stroud.

Description.—The material available is the lower portion of the tergum, of which the lower carinal margin is slightly crushed.

Plate rhomboidal, slightly convex, with a central obtuse carina running the whole extent of the portion preserved. The occludent and upper carinal margins would probably have been found to stand, had the specimen been better preserved, at right angles to each other, and to have been shorter than the scutal and lower carinal margins.

The surface ornamentation consists of a number of well-marked lines of growth, which form an acute angle with the carina and cross it, giving it a nodulous appearance. These growth-lines are traversed by fine longitudinal lineæ, which may have been formed by the so-called epidermis.

FIG. 1.—A curiously fretted rock buried in Keuper Marl. Croft Quarry.

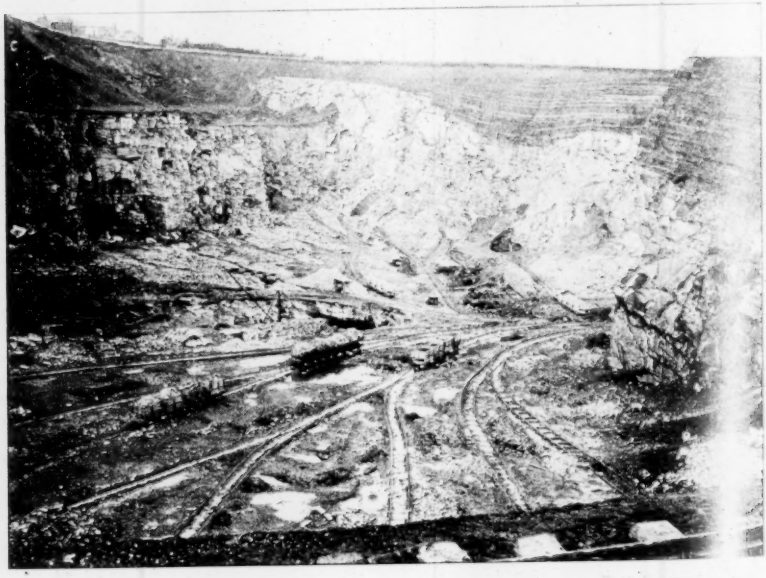


FIG. 2.—Croft Quarry. Syenite and Keuper Marl. Caternary Bedding.

V.—The Origin of the Upper Keuper of Leicestershire.[1]

By T. O. Bosworth, B.A., B.Sc., F.G.S.

(PLATES XV. AND XVI.)

THE following observations on the Upper Keuper are mainly from the Charnwood district, wherein the relations of the Keuper to the older rock beneath are easily studied. The observations are arranged under three heads.

1. *Condition of the Rocks beneath the Keuper.*—For the purpose of contrast the extensive weathering produced by our present moist climate may be first mentioned. This is well seen at Mountsorrel in the section on the east side of the main quarry. Here the granite has been denuded of its Keuper covering and has been exposed to the existing climate. It is disintegrated down to several feet below the surface, and is weathered to a considerable depth. Another good example may be seen at Huncote Quarry, where the South Leicestershire granite is so decomposed that the sand-martins nest in it. Spheroidal weathering occurs here. At Enderby also the Keuper has been removed by denudation, and spheroidal weathering is seen to a depth of 50 feet.

The Coal-measure climate also had a destructive action on these rocks. I know of no section showing Coal-measures deposited on Charnian rocks, but in 1904 I was able to watch boring operations near Peckleton in search of coal. Beneath the Coal-measures, at a depth of some 200 yards, syenite of South Leicestershire type was reached. About 45 feet of this were pierced, all of which was intensely weathered, resembling the South Leicestershire rocks where exposed to this climate.

In marked contrast is the condition of these rocks where they are overlain by Keuper. Everywhere beneath the marl the Charnian rocks are in sound condition right up to the very surface and often indistinguishable from the best stone at the bottom of the quarries. Indeed, the best stone is usually quarried from beneath the Keuper, and older workings in the surface rocks have been abandoned. From what I have seen in the Mendips and South Wales I believe the same surface freshness occurs in the Carboniferous rocks under the Keuper. This remarkable freshness suggests that, while the Charnian Hills were being buried by the Keuper deposits, a desert climate prevailed.

2. *The Surface Features of the Rock beneath the Keuper.*—It has been shown by Professor Watts that the subaerial features of the buried Charnian Hills are very perfectly preserved, with peaks, pinnacles, and precipitous slopes intact. Where the Keuper rests on massive homogeneous igneous rocks, their surfaces are generally smoothed, fretted, and curiously carved. Beautiful examples of wind-worn rocks at Mountsorrel have been described by Professor Watts. But in many other places also there are surfaces highly suggestive of wind erosion, as at Croft, Sapcote, Groby, etc. They are usually

[1] Reprinted by permission from Transactions of the Leicester Literary and Philosophical Society, vol. xii., part 1, 1908, pp. 28–34.

smoothed and pitted, and bear projecting carved knobs which are often coated with a red crust. At Narborough, where the rock is fine-grained and contains no evident quartz, the surface has taken a high polish. At the north-east corner of Croft Quarry a large surface of rock bared for quarrying may now be seen. Part of this was covered by Keuper Marl, and part had been denuded of Keuper by glacial agency and covered by Boulder-clay. The two parts are quite different: the former is comparatively very fresh, and from it project knobs of fretted stone covered with red crust containing round quartz grains; the latter is undulating, bare, and striated (Pl. XV, Fig. 1). At Groby, in the Sheet Hedge Wood Quarry, a precipitous slope was bared about a year ago, on which a vein of quartz projected, whose pitted and fretted surface looked very unlike the work of water, but rather as though blown sand had played upon it, picking out the druses and chloritic grains.

Another curious example I unearthed at Croft, two years ago (see Pl. XV, Fig. 1). It has since been quarried away. Along the joints in this rock fissures had been formed, which widen downwards, the undercutting being greatest on their south sides. This suggests the action of dew. But there is a conspicuous line, above which the surfaces are fretted and the crevices widen upwards. It may be that the rock was subsequently buried in desert dust up to the level of this line, while the part above it was exposed to the wearing action of drifting sand. At Bardon, Shepshed, and generally along the northern border of Charnwood, and also at Woodhouse and Swithland, where the rocks are broken or cleaved, the floor beneath the Keuper is rough and craggy, though the rocks are still comparatively fresh.

Worn slopes occur facing all points of the compass, and their distribution seems to depend most upon the nature of the rocks. Isolated rocks would be more favourably placed for wind-carving, and they would more easily be grooved by sand brushing through narrow gaps between them. Again, only massive and homogeneous stone would stand long enough to become carved, while rocks with cleavage or many divisional planes would crumble too quickly, and would moreover give rise to talus slopes. This may account for the possible wind effects being almost confined to the granitic rocks of Mountsorrel, Groby, and South Leicestershire.

3. *The Nature of the Keuper Deposits.*—In the open country the Keuper beds are almost horizontal, but around Charnwood they are often steeply inclined, and dip everywhere in the direction of the surface slopes on which they lie, the amount of dip depending on the steepness of the slope. Thus there is a radial direction of dip around the Charnian peaks, and where the Keuper is seen occupying depressions in the ancient land surface catenary bedding often occurs, e.g. at Croft and at Groby (Pl. XV, Fig. 2). And from the way the Keuper dips away from the hills it seems probable that the large valleys were filled in the same manner. This inclination of the beds might to some extent be explained by great contraction of the marl on solidification. But we should in that case expect the bending to be accompanied by fractures and slickensides. This, however, is not

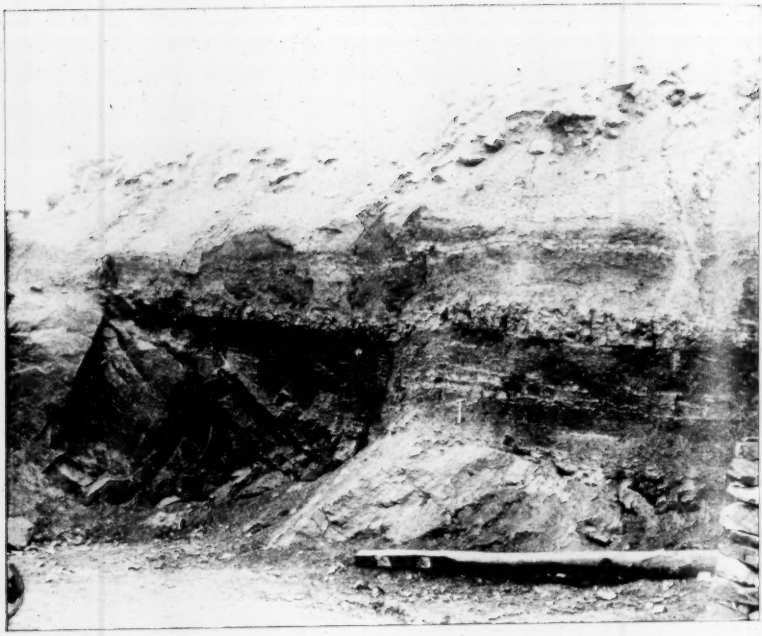


FIG. 3. Bardon Hill Quarry. Stone-band in Keuper Marl starting from a buried crag.

FIG. 4.—Triassic Scree resting against the Syenite at Croft. Croft Quarry.

the case. Except at a distance from the older rocks, any traces of fractures in the Keuper are extremely rare, and there has apparently been little or no post-Triassic faulting in Charnwood. So that it seems probable that the beds were deposited with their present inclinations, somewhat in the manner of the loess.

Near the rocks the marl contains grit and stones, and there is generally a breccia at the base. The stones are of varied sizes; in some cases worn and in some cases very angular, but never smooth like ordinary pebbles. They are in a remarkably fresh condition, and often occur in bands in the marl, recalling the stone beds in the Persian deserts described by Blanford. In South Leicestershire they are much worn and fretted, and of very irregular shapes. They are generally pitted and sometimes polished. A year ago the section along the south end of Croft Quarry showed a 10 foot layer of these stones lying in a matrix of gritty marl. Similar stones occur throughout the 30 feet of marl above, and they are often situated with their grooves and ridges parallel with the bedding, as though they had been carved *in sitû*. Each stone is surrounded by a thin red skin consisting largely of sulphates and carbonates of calcium and magnesium. This skin may be due to mineral matter filling up small spaces between the stone and the marl. Such spaces might well be caused by alternate expansion and contraction of volume, under the influence of temperature changes so marked in desert regions.

The grit particles at Croft are subangular, and some of the green bands are almost entirely composed of them. At Mountsorrel and at Groby there are both worn and angular stones in the Keuper, and some of them are very large. In Cocklow Wood very rounded examples are seen in the bed of a pre-Triassic gully. Considering that the summit of the hill on whose side they occur must have been within 200 yards, their shape is somewhat remarkable. The position of this gully has evidently been determined by a belt of shattered rock beneath. A similar example occurs at Groby, but in this case the stones are angular. At Bardon and Shepshed the stones are angular, and sometimes they lie in bands which may be traced to some crag projecting from the underlying rock slope (Pl. XVI, Fig. 3).

In the most easterly quarry at Groby a coarse breccia rests upon the rock, composed of angular fragments cemented together by white calcareous matter. Here, also, large and very angular blocks of beautifully fresh stone occur a few feet up in the marl. Their edges are extremely sharp, and they bear no traces of water action, but look rather as though they have been splintered off by frost action, and have certainly received no rough treatment since.

A scree sometimes forms the base of the Keuper when the slope beneath is steep. The best example is seen in the quarry incline at Croft, adjacent to an almost precipitous slope which faces south and is seen in section to a depth of some 20 feet. The stones are subangular and fresh (Pl. XVI, Fig. 4). The marl above also dips steeply to the south, but the angle of rest was apparently less for the fine material than for the stones.

All the material in the Keuper which has so far been mentioned is of purely local origin; and the screes, breccias, stone bands, and the grit in the marl are entirely derived from the rocks which they surround. Thus at Narborough these are all of the peculiar Narborough stone; at Mountsorrel they are all granite fragments; at Swithland they are chips of slate, and so on. Nowhere is there any mixture such as would occur in a beach, nor any evidence of shore drift. In this matter the Keuper breccias differ greatly from those of Permian age. Traced away from the hills the marl soon becomes free from grit, and no coarse local detritus seems to have travelled far. But at Woodhouse in a green band there is fine grit which can just be recognised as granite from Mountsorrel, two miles distant. Also at Swannington in marls low down in the Keuper there are sand beds with scraps of slate and quartz which must have travelled about $1\frac{1}{2}$ miles.

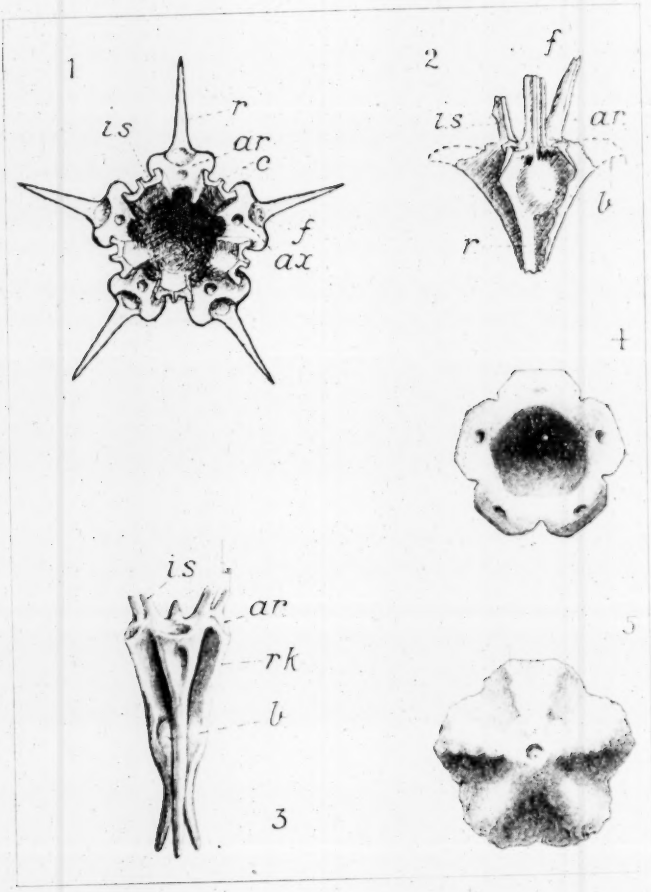
Of the normal Keuper marl there are many varieties. At Silcby both the green and the red beds are sandy, but more usually the red marl is of very fine texture and breaks with conchoidal fracture. Sometimes this has a kind of nodular structure and shows the bedding, and more rarely true laminated beds occur. The colour also varies greatly.

All the evidence of water action I have seen is confined to the green bands in the Keuper, and this evidence points only to shallow streams and salt pools. These green bands always contain quartz sand, and it is my experience that when suitably weathered they almost invariably show ripple-marks, and salt pseudomorphs which are sometimes clustered along the crests of the ripples. The ripple-marks vary greatly in size and character. If they are due to waves controlled by the wind they may indicate its direction.[1] For example, at Nottingham they strike N. 20° W., and at Gipsy Lane, near Leicester, they strike N. 40° W. But I have seen them striking in different directions in layers of the same green bed only half an inch apart.

Upper Keuper Sandstone occurs in lenticular beds at various horizons. It is usually grey and coarse. Near Leicester at the Dane Hills it is nearly 20 feet thick and is very uniformly false-bedded from the south-west. *Estheria* and fish-scales and fragmentary plant-remains lie on the false-bedding planes, which dip at 30 degrees. Very similar beds occur in Warwickshire and Worcestershire. Beds of similar sand dip steeply away from the Charnian inliers of Enderby, Croft, and Stoney Stanton, and they contain nuggets of the local rocks. Some beds consist of almost spherical grains and are apparently desert sand. Rounded grains are also plentiful in the marl, and at the base of the marl in South Leicestershire, resting upon the worn rock surfaces. In South Leicestershire there are no quartz rocks from which these coarse sands could be derived. Along the north and north-east boundaries of Charnwood, the sands are finer.

The heavy minerals also point to a distant source for the material.

[1] The author is collecting data, and would be greatly obliged for any information as to strike of ripple-marks.



New Chalk Crinoids from the '*Micraster cor-testudinarium* zone' of the Upper Chalk, Seaford Head, Sussex: from Dr. Arthur Rowe's Collection.

FIG. 1.—Oral view of *Rowecrinus alata*, gen. & sp. nov., restored. × 17.

" 2.—Lateral view of *R. alata*. × 10.

" 3.—Lateral view of *R. communis*. × 10, restored.

" 4.—Oral view of *R. communis*. × 14, the interradial spine being broken off.

" 5.—Aboral view of *R. communis* var. *rugosa*. × 16.

r, radial wing; *ar*, radial articular facet; *f*, ligament fossa; *ax*, axial canal; *is*, interradial spine; *c*, carina; *b*, basal; *rk*, radial keel.

Heavy mineral separations have been made from a large number of localities throughout the country. The same minerals occur alike in sands and marls, in the grits in contact with the Charnian rocks, in the basal breccias, in the Dolomitic conglomerate, and in the Rhætic sandstones of South Wales.

The most notable feature is the abundance of garnet, particularly in the coarser sands, and in the basement beds resting on the Charnian rocks. This mineral varies in colour between pink and mauve, and contains a large percentage of iron. In some beds the garnets occur as almost perfect spheres, but in others as very angular fragments with conchoidal fractures. In South Leicestershire the heavy minerals often consist chiefly of garnet, but approaching Charnwood the amount of zircon increases, and on the north and north-east borders of Charnwood the proportion of garnet is very small. Tourmaline and rutile occur in smaller quantity, but are a constant constituent of all the separations; they vary much in size and are sometimes very round and smooth. Staurolite is also common. To these heavy minerals the Charnian rocks no doubt have made their contribution, especially in the case of zircon; for powdered South Leicestershire syenite yielded rutile and zircon, and abundant perfect zircons were obtained from decomposed Mountsorrel granite; also the Millstone Grit contains tourmaline. But in the main the heavy minerals of the Keuper must have come from some distant source.

Thus it seems that the Upper Keuper accumulated in a continental basin under desert conditions. Shallow pools and occasional waterflows were a feature of this desert, and much of the greatly worn dust and sand had doubtless been long drifted to and fro, both by wind and by water.

VI.—A Note on some new Chalk Crinoids.

By J. A. Douglas, B.A., F.G.S., University Museum, Oxford.

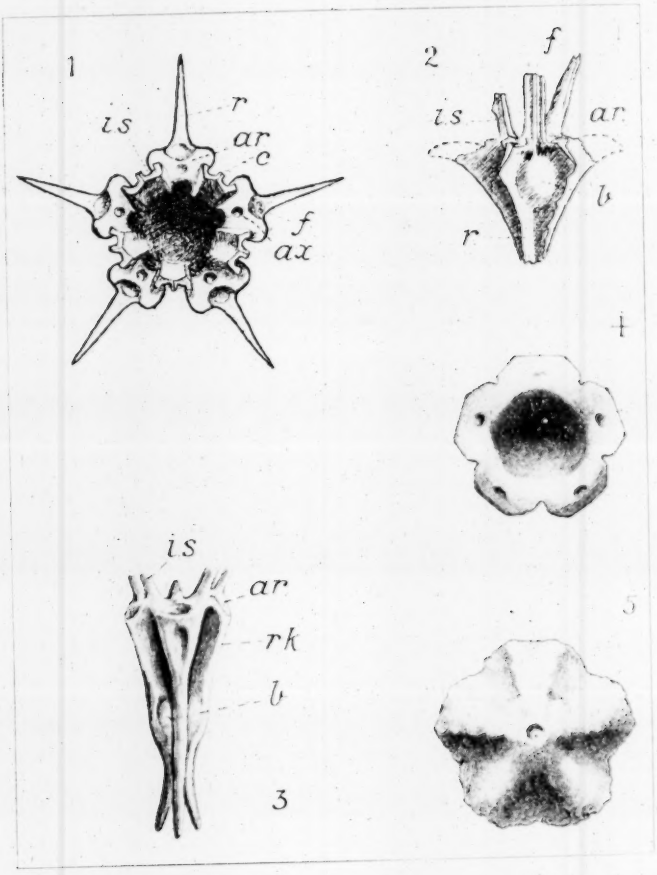
(PLATE XVII.)

THE following is a brief account of some minute Crinoid calyces, which appear to have been hitherto undescribed, sent me by Dr. Arthur Rowe, who obtained them from the *Micraster cortestudinarium* zone of the Upper Chalk.

From the number of specimens it would appear that they are fairly common at certain localities, but I have been unable to detect any traces of arm or stem plates. The calyces are well preserved, and that they are full-grown individuals seems evident from their uniformity in size and solidity.

Mode of Occurrence.—As I am indebted to Dr. Rowe for all my information as to the localities and horizons at which they have been found, I cannot do better than quote his letter to me on the subject:—

"A fossil so minute can only be seen on a well-weathered surface of a hard rock, and the only zones where I have found them *in situ* are those of *Rhynchonella Cuvieri* and *Holaster planus* in the Isle of Wight and at Dover. The best way to get them is from flint meal. Practically all I have, with the above-mentioned exceptions, are from that source. It is necessary, of course, to have hollow flints, and these only occur in quantity at a few favoured localities in the zones of *Micraster*



New Chalk Crinoids from the '*Micraster cor-testudinarium* zone' of the Upper Chalk, Seaford Head, Sussex: from Dr. Arthur Rowe's Collection.

FIG. 1.—Oral view of *Rowecrinus alata*, gen. & sp. nov., restored. × 17.

„ 2.—Lateral view of *R. alata*. × 10.

„ 3.—Lateral view of *R. communis*. × 10, restored.

„ 4.—Oral view of *R. communis*. × 14, the interradial spine broken off.

„ 5.—Aboral view of *R. communis* (var. *rugosa*). × 16.

r, radial wing; *ar*, radial articular facet; *f*, ligament fossa; *ax*, axial canal; *is*, interradial spine; *c*, carina; *b*, basal; *rk*, radial keel.

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cor-testudinarium and *Micraster cor-anguinum*. In none of the other zones are the flints of a suitable nature. The actual range of the calyces is, in ascending sequence:—

4. Zone of *Rhynchonella Cuvieri* } *In situ*. Dover and Isle of Wight.
5. ,, *Holaster planus* ... }
2. ,, *Micraster cor-testudinarium*. Chatham and Seaford (flint meal).
1. ,, *Micraster cor-anguinum*. Chatham, Keston, and Northfleet (flint meal).

I have no doubt that they have a wider range, but the necessary hollow flints are not forthcoming, and it is useless to look for them on soft rock surfaces.

The reason for their great abundance in the *Micraster cor-testudinarium* zone in my collection is that at Seaford Head there is an abundance of the peculiar hollow flints which alone yield flint meal."

Description.

General Characters.—Calyx minute, funnel-shaped, pentagonal or stellate in oral view. Radials five, long, with relatively large articular facets, which are bounded on either side by upright projections given off from their inner lateral margins. These projections are grooved externally, and the lateral projection of one radial fuses with that of the next adjoining to form a single interradial spine, which has a slight inclination outwards, and exhibits a median external carina bounded by two grooves.

The outer, i.e. aboral, face of each radial is provided with a distinct flange. This may be in the form of a rounded keel, the lower end of which is produced downwards and outwards below the base of the calyx, or of a thin wing-like process. In a single instance the flanges were partially obliterated by regular nodular thickening.

Situated between the radials may be seen, in lateral view, rounded or oval thickenings, which from their analogous position to well-marked plates in *Extracrinus* probably represent basals fused into the cup.

The radial articular facets are horizontal, or with a slight outward slope; they usually exhibit external fossæ and central axial canals.

Tegmen, arms, and stem unknown, though the articulation for the latter was observed in one form.

Average dimensions of the common form—

Total length of calyx with radial projections ...	·153 inch.
Length of interradial spines	·013 ,,
Length of downward prolongation of radial ...	·02 ,,
Diameter of calyx without projections	·06 ,,

Affinities.—This minute crinoid possesses certain characters in common with the Liassic '*Extracrinus briareus*,' namely, radials with an external keel and downward prolongations; the latter, however, in *Extracrinus* are jointed, whilst no trace of this is observable in our form. The keels, on the other hand, are developed to a much greater extent.

The fusion of the plates renders comparison difficult, but the unusual development of the radials above mentioned seems to furnish sufficient grounds for the foundation of a new genus, for which I propose the name *Roycecrinus*, after Dr. Rowe, their discoverer.

Two distinct species appear to be well marked.

Roycecrinus alata, sp. nov. (Pl. XVII, Figs. 1, 2).

Calyx stellate in oral view, the rays of the star being formed by the thin wing-like processes of the five radials (Fig. 1, *r.*). The breadth of

the calyx + wings is greatest just below the level of the radial articular surfaces, and is approximately equal to the length; it diminishes rapidly towards the base.

The interior of the calyx is deep, and is bounded by the five compound interradial spines (Figs. 1, 2, *i.s.*). These are slightly concave internally, whilst externally they bear two deep grooves, separated by a median carina (Figs. 1, 2, *c.*). The spines are very long, being more than half the length of the calyx; they have only a slight inclination outwards, and consequently the angle between two adjacent spines is small.

The wings of the radials are visible in an oral view (Fig. 1), and give a characteristic pointed appearance to the external margins of the radial articular facets (Fig. 1, *ar.*). The latter are nearly horizontal, and lie outside the ring of interradial spines. Each bears a distinct external ligament fossa (*f.*), below the general level of the facet and a central axial canal (Fig. 1, *ax.*). Basals five, oval, situated more than half-way up the calyx (Fig. 2, *b.*). Tegmen, arms, and stem unknown.

Roveacrinus communis, sp. nov. (Pl. XVII, Figs. 3, 4.)

In this form the radial flanges are not visible in an oral view; the external margins of the articular surfaces are straight, and consequently the calyx appears pentagonal. Calyx long, narrow, funnel-shaped. The radial flanges are in the form of rounded keels, bifurcating below the articular facet, but produced downwards into single cylindrical projections. The radial articular facet has a slight outward inclination and shows a distinct central axial canal; the interradial projections are shorter and more widely divergent than in *R. alata*. Basals indistinctly marked, situated at a greater distance from the radial articular facets than in *R. alata*. Tegmen, arms, and stem unknown.

R. communis, var. *rugosa*, var. nov. (Pl. XVII, Fig. 5.)

In one specimen, which I regard as a variety of *R. communis*, the radial flanges are partially obliterated by regular nodular thickening, which gives the aboral surface of the calyx a rugose appearance. The articulation for the stem is distinctly visible and appears to be circular.

The specimens figured are from Dr. Rowe's collection from Seaford Head, Sussex.

VII.—The Gavarnie Overthrust, and other Problems in Pyrenean Geology.

By E. E. L. Dixon, B.Sc., F.G.S.

(PLATE XVIII.)

IN view of the interest which *charriages* and extensive overthrusts of low inclination are exciting in various parts of the world, an interest which has steadily increased since Nicol first put forward his explanation of the anomalous position of the Moine gneisses, it may be worth while to place before readers of the Geological Magazine a brief account of a remarkable structure in the Pyrenees, which has been noticed by various geologists, but only recently explained, by

Bresson,[1] as another example of overthrusting, and named by him the "nappe de recouvrement de Gèdre-Gavarnie," after two villages in the neighbourhood. I have the less hesitation in doing this because the phenomena, considering their importance and their setting amidst the magnificent scenery of the lofty central parts of the range, appear to have received less attention from English geologists than they deserve. For these reasons also, other questions in Pyrenean geology are afterwards discussed in the light of some recent observations.

In so far as the account relates to the overthrust, it is merely that part of Bresson's work which I was able, in the short time available, to verify three years ago when my friend, Mr. MacAlister, to whom I am greatly indebted for help in preparing these notes, and myself had the pleasure of visiting the ground under the guidance of Mr. Stuart-Menteath. It is difficult to express adequately our gratitude to Mr. Stuart-Menteath for his kindness in putting himself at our disposal, strangers as we were, and though we cannot follow him in some of his conclusions, to him are due many of the observations on which this account is based.[2] Finally, it should be mentioned, Carez has recently described and illustrated by some admirable photogravures the geology of the whole district in a work[3] which will be referred to again in the sequel.

The Franco-Spanish frontier in the Gavarnie district (Hautes-Pyrénées) follows the chief watershed of the range, and is an important boundary, geographically, geologically, and politically. To the south, under a semi-tropical sun, extends a great area of plateaux, gashed by winding, cañon-like gorges; to the north lies a zone of peak and pinnacle, hanging-valley and cirque, which, though narrower, stretches far beyond the horizon, along which it has the appearance of an angry sea turned to stone. The more immediate cause of this difference has been the great rainfall on the northern side, both now and in the past, when the valleys on that side were occupied by glaciers, but at the same time the geological difference is as profound as the geographical.

The southern plateau-blocks have been carved out of gently-inclined beds, thousands of feet thick in all, chiefly Cretaceous and Eocene. Near the frontier the former system is seen to commence with Campanian Hippurite-limestone, correlative with the zone of *Belemnitella mucronata* of the Chalk, and to overlie, with apparent conformity, a comparatively thin representative of the Permian or

[1] "Etudes sur les formations anciennes des Hautes- et Basses-Pyrénées": Bull. Carte Géol. France, tome xiv (1903), No. 93, pp. 288–68, pl. iv, maps.

[2] Mr. Stuart-Menteath's discoveries in this part of the Pyrenees have provided a starting-point for much of the more recent work; an idea of the development of his own views during the controversy over the Gavarnie rocks may best be obtained by referring to his book on "Pyrenean Geology" (parts 1–8, London, 1906–7), especially to the following pages:—Pt. 3, pp. 14–15; pt. 4, p. 26; pt. 5, pp. 5–7, 17; pt. 6, pp. 7, 12, 15–17, 26, 29, 30; pts. 7 and 8, pp. 2, 25–26. In the same work he deals also with the general question of *charriages* on lines to which we shall have occasion to refer later. He has increased my indebtedness to him by checking the statements of fact made in this paper, and by adding an appendix.

[3] "Géologie des Pyrénées Françaises": Mém. Carte Géol. France, tome i (1904).

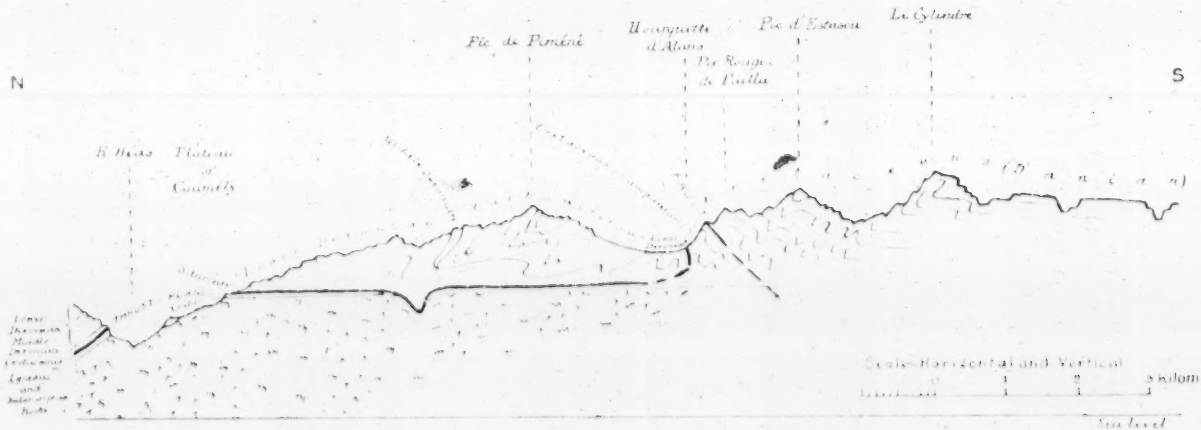


FIG. 1.—Section across the Gavarnie Overthrust, along the line shown in Fig. 2. (Chiefly after Bresson.)

Trias, which in its turn rests with the strongest possible unconformity[1] on a wide, even platform of far older rocks, notably crystalline schists and granite. But on the northern side the formations and structures are as varied as the surface-features, including, as they do, a practically complete sequence of stratified rocks, pierced by igneous intrusions of all kinds, and thrown into apparently hopeless confusion by innumerable faults and folds. Under these circumstances it is especially interesting to find that, according to Bresson's views, near the frontier itself, in the Gavarnie district, the northern side overlaps the southern. Exposures in deep valleys in that neighbourhood show clearly, as we shall see, that a wide sheet made up of a complex of Palæozoic rocks, which, by various characteristics, are linked with those forming the northern zone, has been forced southward, by intense tangential pressure, for several miles over the southern plateau. In its progress it has cleared away almost the whole of the beds which once rested on the underlying, apparently immovable platform of crystalline rocks, but has left still in place, and almost unaffected, a thin layer, generally 10–15 m. thick, of the basement-beds of the Hippurite-limestone, but has crumpled up to a prodigious extent higher horizons in the region immediately beyond where it came to rest. In somewhat the same way a snow-plough leaves a thin layer of snow on the ground and heaves up what lies immediately in front. The analogy is the more complete, as the overthrust mass appears to have come to a standstill with its front still buried deeply, and possibly even somewhat overhung by the beds opposing its advance. (See Fig. 1.) The basal platform has not, however, entirely escaped distortion, for several sharp 'tucks' along the top testify to the intensity of the compression it has undergone. One of these, shown diagrammatically beneath the words 'Middle Devonian' on Fig. 1, has been described and figured by Bresson (op. cit., pp. 247–8, pl. iv, fig. 2) and Carez (op. cit., pl. viii, fig. 1), whilst another, discovered by Mr. Stuart-Menteath, will be mentioned later.

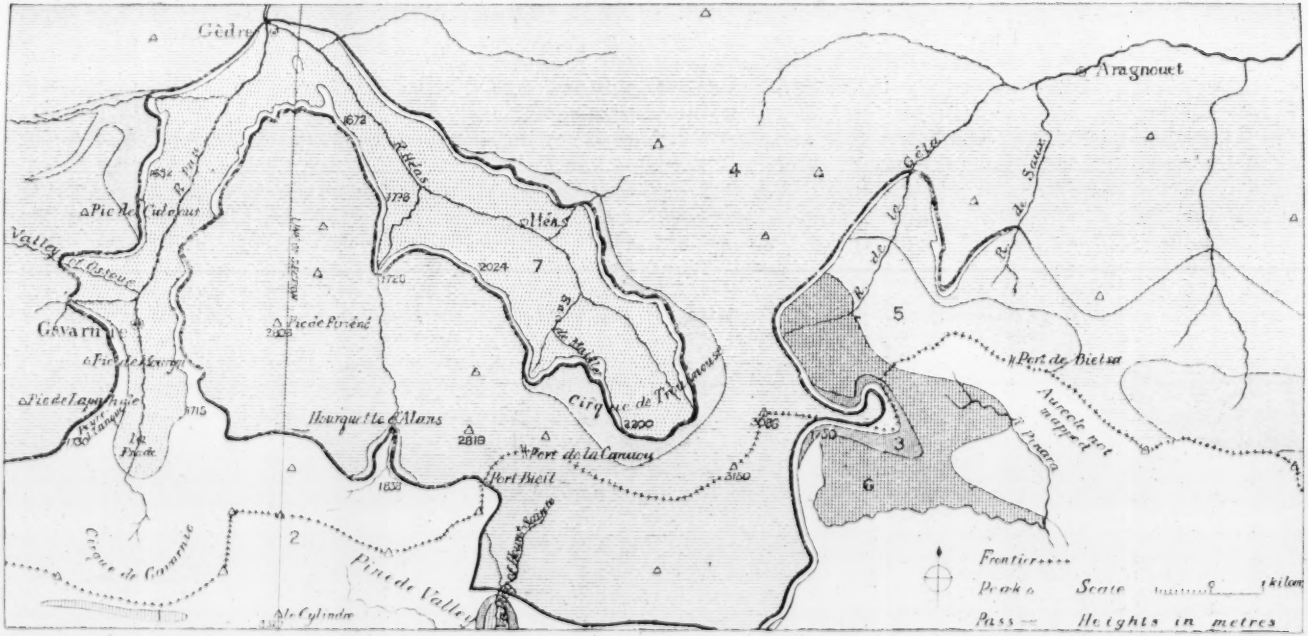
In some such way as this we may interpret Bresson's conclusion that a sheet of Palæozoic rocks has been thrust from the north over the Hippurite-limestone. That conclusion is based on the following evidence.

The valleys in which the structure is exposed, those of the Géla, Héas, and Pau on the French side, and various branches of the Pinède valley on the Spanish side, are shown on Fig. 2, reduced from the French Geological Survey map,[2] together with the rocks of the basal platform, the Trias and Cretaceous above, and the Palæozoic complex which is supposed to have been thrust over all.

The relationships of the outcrop of the Trias and Cretaceous to that of the Palæozoics and to the course of the valleys throughout the area are seen at once from the map and Pl. XVIII, Fig. 1, which illustrates the essential features of almost any part of the district. It represents the Gavarnie (Pau) valley, just above Gavarnie, as seen

[1] As will be seen later, Carez would probably regard one or both of these junctions as overthrusts.

[2] Carte Géol. 1/80. 251, feuille de Luz, 1906.


Gèdre
Aragnouet
Pic de Cudoius
Vallée de Listeure
Gavarnie
Pic de Perdiguère
Pic de Lavigne
Pic de Perdiguère
Pic de Perdiguère
Pic de Tainguy
Pic de Perdiguère
Pic de Perdiguère
Pic de Perdiguère

from the path leading to the Hourquette d'Alans by an observer looking westward toward Vignemale (3,298 m.), which, with its glaciers, appears in the distance. The lower declivities of the valley, below the gentle slopes stretching into the middle distance, form a deep, steep-sided trench in the crystalline rocks of the basal platform. The western (further) side of this trench is seen as a steep slope streaked by light-coloured talus. At the top the thin sheet of Cretaceous limestones resting on the platform appears in the middle of the view as a dark, discontinuous band, falling gently northward (see also Fig. 3). It turns into the side valley, the valley of Ossoue, which drains the slopes of Vignemale itself, and on the northern side it is conspicuous on the ground, though barely distinguishable in the figure, beneath two dark bands in the lower slopes of the Pic de Culaous. Outside the view it swings round again and continues down the main valley. On the eastern side it is not seen in the figure as it crops out along the brink of the deep trench. Above it the contours on both sides are more irregular, the Palæozoic rocks which give rise to them exhibiting great variety of hardness and structure. Thus the Pics de Mourgat and Lapahule seen immediately above the western side of the main valley, have been found by the French geologists to be composed respectively of Middle Devonian limestone and Carboniferous limestones, etc., separated by Lower Devonian slates across the intervening *col*.

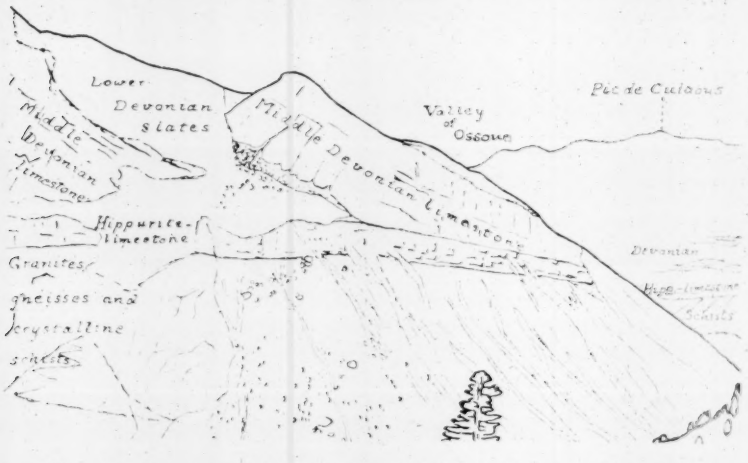


Fig. 3.—Structure of the lower part of the Pic de Mourgat. The summit is hidden. (From a photograph.)

The structure, according to their mapping, of the lower part of the Pic de Mourgat, as well as the outcrops of the Cretaceous and crystalline rocks below, is more clearly seen in Fig. 3, drawn from a photograph. In Pl. XVIII, Fig. 1, the dark bands in the northern

slopes of the valley of Ossoue indicate infolds of Lower Devonian (in a complex of other Devonian rocks), and on the observer's side of the main valley the gentle slopes above the deep trench mark a wide outcrop of soft slates of the same age.

It is clear, then, from this evidence alone, that there is a *prima facie* case that the Palæozoics overlie the narrow outcrop of limestone, but to prove that they have been overthrust further evidence on the following questions is necessary. (1) Has the limestone been correctly identified as Cretaceous and the rocks of the higher ground as Palæozoic? (2) Do the latter really overlie the limestone? (3) Is the junction of the two a plane of movement, or can their relative positions, if abnormal, be explained by a recumbent fold? Further, the question of the root of the overthrust should be considered.

The first point is readily settled. At various places the limestone yields an abundance of typical hippurites, which not only demonstrate its Cretaceous age, but have enabled the French geologists to assign it definitely to the Campanian subdivision. Stratigraphical evidence is also forthcoming, for in Spain, in the Pinède valley, as already pointed out by Stuart-Menteath,[1] it is visibly continuous with the Campanian of the plateau-region, where the sequence up to the highest beds (Eocene) is normal. As regards the rocks of the high ground between the valleys, there has never been any doubt as to their age. They are sufficiently fossiliferous to show, according to all who have worked on them, that they constitute a complex of Silurian, Devonian, and Carboniferous rocks. By means of its fossils, that part which is shown in Pl. XVIII. Fig. 1, has, with the rest, been unravelled by Bresson, Stuart-Menteath, and others. The unanimity with which the rocks had been regarded as Palæozoic by Pyrenean geologists led to our devoting our time chiefly to other questions, especially as their aspect throughout was quite in keeping with that view. In connexion, however, with what follows, it may be mentioned that Bresson's statement that Lower Devonian rocks form a great part of the high frontier-ridge separating the cirque de Troumouse from the valley of Hount-Sainte in Spain, was seen to be justified on the occasion of our traverse when Mr. Stuart-Menteath identified as Coblentzian forms some trilobites, etc., which we found near the pass of la Canaou.

Turning next to the order of superposition, it is at once obvious in the field that the band of Campanian in its course along the valleys generally contours the slopes in a way which is explicable only on the assumption that it is the outcrop of a thin sheet of great extent but slight (northerly) inclination which has been dissected by erosion but still exists beneath the Palæozoic rocks forming the high ground. A closer examination confirms this conclusion, and at the same time shows that the dip of the bedding in the limestone is, in general, equally slight, and conforms with the junction with the basement-platform of old rocks below. Steep inclinations are few and local, except near Gèdre where the land disappears northward, plunging steeply, according to Bresson (loc. cit., pp. 243, 249, 250, figs. 65, 69, 79), beneath the Palæozoic rocks which bound it in that direction. The

[1] "Pyrenean Geology," pt. 6 (1906), p. 26.

sporadic occurrences of folding in the Cretaceous sheet and the basement-platform below do not militate against Bresson's theory of overthrusting, as they do not explain the occurrence of Palæozoic rocks in the higher ground, and, in fact, may be regarded as 'tucks' in the otherwise undistorted floor of the overthrust.

At some places such as Peyreblanque, a short distance to the south of the scene of Pl. XVIII, Fig. 1, the Cretaceous sheet, horizontal and yielding abundant hippurites, gives rise to a distinct terrace along the side of the valley, below the higher ground formed of Palæozoic rocks. But its relations to the latter are most strikingly shown in the neighbourhood of the cirque de Troumouse, at the head of the Héas Valley. There the high, wide ledge which constitutes the floor of the cirque is formed essentially of the approximately horizontal basement-platform of crystalline rocks, in part still covered with a thin, gently undulating veneer of hippurite-limestones, on which, near the steep walls enclosing the cirque on three sides, rests chiastolite-slate. This slate has been proved to be Silurian by Bresson's discovery in it of a characteristic *Orthoceras*-limestone (op. cit., p. 246). Its superposition on the hippurite-limestones is equally unquestionable, for in the left bank of the Maillet stream it visibly overlies limestones, which on the opposite side have been bared over a wide, flat area, and contain typical hippurites. The position of affairs may be gathered from Pl. XVIII, Fig. 2, in which in the foreground is seen the wide area (its surface parallel to the bedding) of white, hippurite-limestone, whilst behind the figure rises a low, vertical cliff of dark chiastolite-slate, at the top of which the ground recedes at a gentle gradient to the steep bank just visible in the background. This bank is really the foot of the northern slope of the frontier-ridge, the crest of which rises two to three thousand feet above the floor of the cirque, and which is made up entirely of various Palæozoic formations, including, near the Port de la Canaou as already mentioned, Lower Devonian to a great extent. Nevertheless, on crossing by the 'port' into the valley of Hount-Sainte, it is found that, on the southern side also, these old rocks rest on a thin sheet of hippurite-limestone, at a level which is not greatly different from that on the northern side, four kilometres distant. When we consider further that the limestone on both sides is but slightly inclined and is underlain by an even basement-platform of far older rocks, from which it is separated on the southern side by a thin group merely of Permo-Triassic beds, we are forced to conclude that the platform with its thin covering of hippurite-limestone forms the foundation of the ridge from side to side, and underlies the whole Palæozoic mass above. This conclusion being precisely similar to that drawn from the evidence of outcrops along the valleys on the French side, we are justified in saying that a complex of Palæozoic rocks rests on a sheet of Cretaceous limestones, dipping slightly north, over an area which extends at least from the latitude of Gèdre to an irregular line near the frontier, a width of ten kilometres, and from the valley of Saux in the east to beyond that of the Pau in the west, a length of more than 18 kilometres.

As regards the issue between overthrust and recumbent fold, Bresson has shown (op. cit., p. 246, etc.) that both the thin group

of Cretaceous limestones and, in some places, the Palæozoics immediately above, retain, *intra se*, their original order of superposition, and have not been reversed, thus putting a recumbent fold out of court. Also the junction itself bears witness to a lateral thrust of the most powerful kind. This is clearly the case in the cirque of Troumouse at the exposure previously mentioned. The chiastolite-slate has suffered most, as it has been 'pugged up' or mylonised for some distance above the junction, but, though it has proved such an excellent lubricant that undistorted hippurites may be found in the limestone a short distance below, nevertheless the latter has also had a rough time. This is evident from the occurrence in the 'pugged up' slate of large and small 'augen' (shown in Pl. XVIII, Fig. 2) of limestone torn from the sheet below, and from the presence of shear-zones in the limestone itself, even down to its base. Along these zones the limestone has been reduced to a fine-grained, platy mylonite. Unfortunately on the occasion of our visit slickensiding of the upper surface of the limestone was not accessible and the direction of movement of the slates, therefore, not directly determinable, on account of weathering along the junction.

Finally, Bresson points out that the overthrust Palæozoics must have moved in a southerly direction; this is obvious from the fact that there is, or has recently been, an unbroken mantle of younger rocks for a great distance to the south, whereas to the north, in which direction the thrust-plane is inclined, Palæozoic rocks, similar in facies to and continuous with the overthrust mass, extend far beyond Gèdre and the valley of Saux, where the underlying Cretaceous limestone disappears, and with it evidence of the movement. In fact, as the rocks and structures above the exposed portion of the thrust-plane are similar to those of the disturbed zone to the north, it is difficult, if not impossible, to say where the overthrust begins or by how much its full width may exceed the 10 kilometres which, as we have seen, is exposed. The view that it came from the north is fully borne out by the inclination of the folds (Fig. 1) in both the overthrust rocks themselves and the Cretaceous mass piled up in front. The folding of the latter is remarkable, and is beautifully figured by Carez. That the southward movement encountered great resistance is suggested by this folding and confirmed by the remarkable form of the front of the thrust-plane, which instead of sloping steadily upward ends southward as a steep fault with an irregular east-and-west course, and, in places, with possibly even a southerly hade like a normal fault.[1]

The evidence which has been cited amply justifies, I think, Bresson's *charriage*. In fact, although it forms but a part of what has been worked out with much care by Bresson himself, it would not have been given at such length were it not that the truth of parts of it have been questioned and, more particularly, that another and much larger overthrust has been stated to exist, in the same region but on the strength of evidence which, in contrast to that of Bresson, appears to me so slight as not to justify such sweeping conclusions.

The discussion of this second problem has been prompted by some

[1] Bresson, op. cit., fig. 75.

recent publications on the Pyrenees.[1] In the first two, Mr. Stuart-Menteath, unfortunately, introduces disparaging references to Darwin and others, which are as germane to the case as "the flowers that bloom in the spring," and only serve to repel proper consideration of his other contentions. These last are directed against the degree to which the theory of overthrusting has been pushed in the Pyrenees, for he maintains that in the western part of the range (feuilles de Bayonne et de St. Jean-Pied-de-Port) gigantic overthrusts have been invoked in order to explain anomalies which do not in reality exist, as they arise from the incorrect identification of various outcrops. He particularly challenges some of Termier's conclusions. As Termier has cited[2] as corroborative evidence the existence at Gavarnie of a *charriage* which has 'carted' the Upper Cretaceous from the Spanish side across a strip of country 200 kilometres long, a consideration of the latter instance is evidently of more than local interest; as Termier says " . . . s'il y a *charriage*, le phénomène est général et embrasse tous les dépôts crétacés, de part et d'autre, de l'axe pyrénéen, et même toutes les Pyrénées."

To Carez is due this view that the Cretaceous at Gavarnie has been thrust from the south over the crystalline rocks on which they now rest. Stuart-Menteath, Bresson, and others, have maintained that the hippurite-limestone of the Gavarnie district is in its original position relative to the platform below. In the work previously cited, though the Palæozoic rocks are shown by Bresson to have been thrust over the Cretaceous from the north, the latter is stated to be in place because its basement-bed contains not only pebbles of quartz and, occasionally (op. cit., p. 247), of the subjacent schists, but also a littoral fauna (oysters, etc.). He apparently regards the even plane on which it rests as worn down by the Cretaceous sea. Carez, on the other hand, gives nine reasons, under the following heads, for regarding the Cretaceous as overthrust from the south :—[3]

1. Absence of any littoral band at the base of the Cretaceous.
2. Existence of an even, planed surface, forming the 'substratum' of the Cretaceous.
3. Absolute difference of facies between the Cretaceous of Gavarnie and neighbouring places, and the beds of the same age in the northern plain.
4. Absence of the Jurassic and the Lower Cretaceous at Gavarnie.
5. Impossibility of admitting the simultaneous deposition of the Upper Cretaceous at Gavarnie and in the northern plain.
6. Almost horizontal position of the Cretaceous of the frontier.
7. Priority of the folding of the rocks of the 'substratum' to the attainment by the Cretaceous of its present position.
8. Junction by a fault of the Palæozoics and the Cretaceous at

[1] P. W. Stuart-Menteath : "Sur les Méthodes de la Nouvelle Géologie," 1907; "La Nouvelle Géologie à Biarritz" (Extrait de 'Biarritz-Association'), pts. 1 and 2, (1907 and 1908). P. Termier, "Sur la Structure Géologique des Pyrénées occidentales," C.R. Ac. Sc., tome cxli (1905), p. 966. L. Carez, "Géologie des Pyrénées françaises," Mém. Carte Géol. Fr., fasc. i–iv (1903–6).

[2] Op. cit., p. 966.

[3] Op. cit., fasc. ii (feuilles de Tarbes et de Luz) (1904), p. 1156.

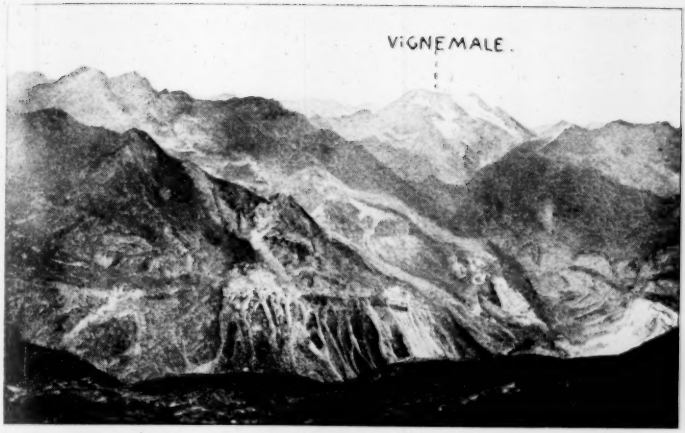


Fig. 1.—The Pau Valley, from the Hourquette d'Alans.

Fig. 2.—Silurian Slates (S.s.) thrust over Hippurite Limestone (H.l.), Maillet brook, Cirque de Troumouse. Fr.P.=foot of the frontier ridge (Palæozoics). The almost horizontal limestone in the foreground is bared over a considerable area; behind the figure rises a low vertical cliff of the slates with "augen" torn from the limestone in the lower part (H.l.a.).

Port-Bielh and other places along the southern margin of the overthrust Palæozoics.

9. Intensely folded nature of the Upper Cretaceous.

The following is a summary of his expansion of these arguments, with comments in square brackets:—

1. He has "not seen a single pebble at the base." In places the lowest beds contain quartz grains or some subangular fragments of quartz, but the latter are very rare and disseminated also throughout the limestone. The subangular fragments of the 'substratum,' which are found, though also very rarely, at the base, are more easily explained on the hypothesis of an overthrust than on that of a transgression of the Cretaceous sea. [It appeared to us, on the contrary, that quartz-fragments were frequent at the base of the limestone, but rare or absent at higher horizons. Their evidence, however, is inconclusive, though the hypothesis of an overthrust leaves unexplained the general absence of fragments of other hard rocks, which make up a large part of the 'substratum.']

As regards the basal fauna, Carez doubts whether it is littoral, as that of the Lower Danian is deep-sea, but in any case it merely indicates a slight depth of water, not the proximity of a coastline. [Here again the evidence is inconclusive, though the persistence, apparently admitted by Carez, over a wide area of an exceptional fauna in the 'sole' of the supposed overthrust is remarkable.]

2. Carez says that the surface of the 'substratum' is "planed down, I will even say polished." He further remarks, as opposed to Bresson's idea that this surface is a sea-bottom, that "the erosive action of the sea is exercised on its coasts, but never on the bottom." On the other hand, the smoothing of the 'substratum' of an overthrust is to be expected, and "the presence of a plane surface beneath the Cretaceous, so far from proving the latter's deposition in place, is one of the best arguments in favour of the theory of *charriage*." [This argument would, in fact, be almost conclusive, were the surface of the 'substratum' everywhere polished. But though this may be the case in places, it certainly is not universally so, and the occurrence of even a single place yielding clear evidence that the limestone has been deposited on the 'substratum,' such as that described later (pp. 372–3), is sufficient to disprove Carez' *charriage*. Instances of movement and polishing along the junction are to be expected in view of the great overthrust, previously described, a short distance above. Nevertheless, at the cirque de Troumouse (p. 366), where mylonisation was noticed at the base of the limestone, the evidence pointed, not to a general movement along the junction, but to a local one crossing it.]

3. Carez remarks that the Upper Cretaceous of Gavarnie and neighbouring places belongs to the southern or hippurite-limestone facies, whereas contemporaneous beds to the north, though at one place distant merely a mile, yield a northern fauna which is completely different, an abruptness of change which cannot be original. [Other disturbances, known to exist in the neighbourhood, may account for this abruptness of change. Of the minimum distance necessary to have effected the change in the Cretaceous sea our knowledge is probably uncertain.]

4. Carez draws a similar conclusion from the fact that although Jurassic and Lower Cretaceous rocks are absent from Garvanie, etc., they are represented to the north, at one place at a distance of a mile, by more than 2,000 metres of rocks (compact limestones, etc.) which were "certainly deposited far from a coast-line." This argument is a variation of the preceding. When Carez remarks that everywhere in the southern region the Campanian rests on Palæozoic rocks he overlooks the fact, previously pointed out by Bresson and others, that in that part of the region which lies in Spain it is separated therefrom by Permo-Trias. On Carez' view this is explicable only on the supposition that in that district his overthrust separates the Campanian from the Permo-Trias, a point to which we shall return later. The discordance at the base of the Campanian to which he alludes has been explained by the above authors as the result of a widespread hydrocratic movement. This view is much more probable than Carez', which involves the supposition that a thrust-plane has persisted at one horizon throughout its visible extent of many miles.

5. As it is difficult to follow Carez here I will quote his argument in full (pp. 1157–8): "La différence d'altitude actuelle entre les dépôts crétacés de la crête frontière et ceux de la plaine [septentrionale] dépasse 3,000 mètres. Or, si le Campanien n'a pas le même faciès dans les deux zones, en revanche le Danien est identique, tant au point de vue de sa composition pétrographique que de sa faune. Leymerie avait déjà été frappé de ce fait, et il en avait conclu, avec raison, que le soulèvement de la zone frontière était postérieur au dépôt du Crétacé qui la constitue. C'est ce qui me paraît démontré: les fossiles daniens ne vivaient pas à Montgaillard et dans la Haute-Garonne sous une profondeur d'eau de plus de 3,000 mètres, et cette colossale différence d'altitude entre des sédiments identiques est indubitablement le résultat de mouvements postérieurs à leur dépôt." Undoubtedly, but as a whole series of mountain-structures of Tertiary age separates the two areas where contemporaneous deposits differ in altitude by 3,000 metres, it would seem that this difference of level demands no further explanation.

6. After referring to the gentle inclination of the Campanian sheet and to the Tertiary age of the principal orogenic movement in the Pyrenees, Carez asks, "How explain, on the theory of deposition in place, that this gigantic movement has not affected the Cretaceous rocks?" As already pointed out by Bresson, the Cretaceous sheet is folded or sheared at several places, phenomena which are doubtless connected with the Tertiary overthrust of Palæozoic rocks from the north, previously described. On the whole, however, it is undisturbed, a fact which is not only difficult of explanation on the hypothesis that the Cretaceous sheet has been overthrust in the opposite direction to that taken by the overlying Palæozoics, but is readily explicable if we regard the sheet and its basement-platform as part of the base of the plateau-blocks of the Spanish side, which has been buried, over an area of many square miles, beneath the overlapping northern rocks. Again, the Permo-Trias beneath the Cretaceous sheet in the valley of Hount-Sainte cannot, in the absence of any internal or external evidence of movement, be supposed to have been overthrust, as it is

too soft to have stood the journey without a trace of fatigue, and yet it is practically unaffected by the Tertiary movements. Why, therefore, suppose the equally undisturbed Cretaceous rocks which rest on it to have been overthrust? And if the latter be admitted to be in place, the whole case for the overthrust of the Cretaceous sheet at Gavarnie fails.]

Carez further remarks that at the entrance of the cirque of Gavarnie the bedding of the Campanian is not parallel to the surface of the underlying 'Primary' rocks. [This is true of the upper part at the place indicated by Carez, where the Campanian sheet thickens beneath the margin of the overlying Palæozoics, but not of the base, the part which counts; the latter remains parallel to the underlying platform.]

7. Carez considers that the Tertiary upheaval has been the only movement of importance evidenced in the Pyrenees, to the exclusion even of Hercynian and older crust-creeps. If this were true the junction of the undistorted Cretaceous in the Gavarnie district, etc., with the contorted rocks of the basement-platform would obviously be a fault, but as he admits that his views are not shared by the majority of geologists he does not press the point. [*En passant* it is interesting to note that the structures of the rocks in the basement-platform are, by different observers, regarded as Archæan, Hercynian, or Tertiary!]

8. Carez points out that at certain places [along the southern margin of the overthrust Palæozoic mass] the Cretaceous abuts against that mass, though generally passing below it. He explains this fact by unequal advancement of the Cretaceous from the south against resistance. [It is more simply explained by unequal advancement of the Palæozoic mass from the north against resistance, a movement which is admitted by Carez and is independent of his overthrust. In fact, the abutting merely proves relative movement between the juxtaposed Palæozoic and Cretaceous rocks, and has no bearing on the relations of the latter to the underlying platform. Also it appears from his statement that he supposes the Cretaceous to have forced its way *beneath* the Palæozoic mass, and that in the form of an apparently undisturbed sheet, several miles wide at least, but only a few yards thick.]

9. Carez says, "Although the contact of the Upper Cretaceous with its 'substratum' is remarkably plane, the former is itself strongly folded." Proceeding to his application of the argument in the Gavarnie district we read: "At Gavarnie the Cretaceous beds are intensely folded, and their structure contrasts singularly with that of the same horizons on the Spanish side, notably in the valley of Arasas. These are indeed the characters of an overthrust mass of which the front is folded several times on itself, although, at a certain distance behind, the beds have preserved a relative regularity." [Passing over the discrepancy between this argument and No. 6, we would point out that although the Cretaceous sheet is folded in places, yet its 'substratum' of crystalline rocks has been folded with it. The folding, in fact, proves not that there has been relative movement between the Cretaceous and its 'substratum,' but merely that they (i.e. really the 'substratum') have not been absolutely rigid under

powerful lateral compression, the former play of which is sufficiently evidenced by Bresson's overthrust. The intense folding to which Carez refers is confined, so far as is known, to the higher horizons of the Cretaceous near the frontier. His figures are beautiful views of the conspicuous folds in the Danian of the upper part of the cirque of Gavarnie, whereas the beds which rest on the platform are invariably the underlying Campanian. Not only is it clear that these folds do not point to relative movement between the Campanian and its 'substratum,' but also the only possible direction of such movement, i.e. from the south, is non-suited, by the inclination of the folds, which lean towards the south instead of the north, and by the fact that the 'front' of the supposed overthrust mass would be, not the folded beds of the frontier as stated by Carez, but the comparatively undisturbed sheet of Campanian, which extends for miles to the north. The folds, as previously mentioned, are readily explained as the result of the southward advance of the Palæozoic mass against resistance.

Thus it appears that the various facts brought forward by Carez in support of his view that the Campanian rocks have been thrust from the south over the basement-platform can all be explained in other ways. It will have been noticed that he adduces no direct evidence of movement along the supposed thrust-plane, though he remarks (p. 1155) that the surface of the basement-platform is "rabotée, je dirai même polie." Very likely this surface in places is a plane of movement, seeing that it separates rocks of very different rigidities and occurs but a short distance below the great overthrust previously described, but, as we shall now see, there is every reason to believe that it is generally a surface of original deposition.

It may be readily examined near Gavarnie in the valley-side to the south-west of the bridge at La Prade de Saint-Jean, where the basement-platform appears to have been forced by intense lateral pressure to take in one of the sharp 'tucks' previously mentioned (p. 366), in which has been nipped a crushed syncline of the overlying Campanian limestone, in the form of a long tongue passing down obliquely for a considerable distance into the mass of crystalline schists. This tongue, which had been previously discovered by Mr. Stuart-Menteath, we found to be bounded along its southern wall by a shear-zone which had affected schists and limestone alike, but at the bottom it was evident that the junction left the plane of shearing, and along the other wall showed its character that it was a surface of deposition unmodified by shearing or friction-brecciation. The limestone adhered closely to the schists, filling inequalities in their surface, and showed no trace of subsequent movement, either in its matrix, which was similar to and continuous with the rest of the Campanian, or in the included fragments of hippurites, which would have at once betrayed shearing by their distortion, even though the intermingled quartz-fragments retained their original form. Also the latter were certainly more numerous than at higher horizons of the Campanian, where, Carez says (p. 1154), they also occur "disséminés dans toute la hauteur de la couche."

Although it is sufficient, in order to disprove Carez' overthrust, to show at any place that the junction of the Cretaceous limestone with

the underlying crystalline rocks is original, and not due to movement, it may be mentioned that it presented similar features at most of the other exposures which were examined. These lay along the even upper surface of the basement-platform, where, on Carez' hypothesis, pronounced evidence of overthrusting would be expected. And even in the banks of the Maillet stream in the cirque de Troumouse (Pl. XVIII, Fig. 2), where the junction is disturbed by shearing, accompanied by mylonisation of the limestone, it does not coincide in direction with the movement, which is probably connected with the adjacent overthrust previously described.

(To be concluded in our next Number.)

NOTICES OF MEMOIRS.

I.—The Geology of the Tahan Range.[1] By J. B. Scrivenor, Geologist, F.M.S.

THE following account of the geology of the Tahan Range is based chiefly on notes collected during an ascent of Gunong Tahan in May, 1906, and subsequent journeys in Pahang.

The Tahan Range is remarkable in being composed almost entirely, as far as is known, of a series of estuarine rocks—comprising shale, sandstone, grit, and conglomerate—which is provisionally named the Tembeling Series. The main range of the Peninsula, which, although greatly more extensive in length, rises very little higher than Gunong Tahan, is believed to be all granite and its modifications, but for occasional areas of schistose rocks, representing altered sediments.

Two ranges, similar to the Tahan Range, but on a smaller scale, are known in the Federated Malay States. One of these is a long range of low hills in the west of Pahang, parallel to the main range, and referred to elsewhere as the Bentong-Telom Range; the other is the small isolated Semanggol Range, forming the border between Larut and Krian in Perak.

No direct evidence of the age of this series of estuarine rocks has yet been derived from the Tembeling District of Pahang; but fossils discovered elsewhere point to a range in time dating from the Rhætic to the Inferior Oolite. The collections made, however, are not numerous, either in specimens or species.

The breadth of the outcrop of the Tembeling Series in the typical district is about thirty-five miles. The strike is roughly N.N.W.-S.S.E., and there is reason to suppose that the series extends into Johore, reappearing as far south as Singapore. The Tahan Range lies on the western side of the outcrop. It would appear that the Tembeling River, whose general course in the upper reaches is to the west, has been turned south by this enormous barrier.

[1] From the Journ. Federated Malay States Museum, vol. iii, January 29th, 1907 (printed April, 1908).

On either side the Tembeling Series is flanked by a wide outcrop of calcareous rocks and associated igneous rocks, named provisionally the Raub Series and the Pahang Volcanic Series respectively. One of the remarkable ranges of limestone hills belonging to the Raub Series was seen from the top of Gunong Tahan and visited later by the writer. It lies to the west of the range and is situated near Kampong Chernal in the Ulu of the Tanum, a left tributary of the Julai. From a peak in this limestone range a magnificent view of the Tahan Range, about fifteen miles distant, was obtained; and it appeared to the writer that it would be easier to ascend Gunong Tahan from this side than from the east.

Petrologically the conglomerate is remarkable for containing numerous pebbles of chert and carbonaceous shale with Radiolaria and Foraminifera. It is believed that these pebbles were derived from beds of similar chert and carbonaceous shale in the west of Pahang. The majority of the pebbles in the conglomerate are sandstone and quartz. The matrix is quartzose. The sandstone afforded andalusite on separating the grains by means of heavy liquids, and also a few grains of zircon and other minerals. In the Tahan River greenish schistose grits were found to contain a little tourmaline. The shale is generally red, owing to surface weathering.

On the gravel banks of the Tahan River there are found pebbles of quartz-porphyry and of a basic rock, which is of the same composition as dolerite. No outcrops of either rock *in situ* were found here; but elsewhere data have been collected which make it probable that this rock is younger, not only than the Tembeling Series, but also than the granite of the Federated Malay States.

In the Rivers Tekai, Tembeling, and Tahan there is abundant evidence of the Tembeling Series having been thrown into a series of anticlines and synclines. In the part of the Tahan Range visited the predominant dip is about 45° W.S.W.

Malays can still be found who hint vaguely and mysteriously at mineral wealth in the Tahan Range. That small quantities of gold occur is extremely probable, and the presence of tourmaline makes it necessary to admit the possibility of tin ore being found also. To the prospector, however, the indications are most unattractive. The range would make an ideal health station.

II.—The Tenth Meeting of the International Geological Congress, held in the City of Mexico, 1906.

THE Compte Rendu de la Dixième Session (du) Congrès Géologique International, Mexico, 1906, has now been published. It consists of two parts, each measuring 11 inches by 8 inches, containing in all 1,358 pages, 56 plates or maps outside the text, and 42 figures in the text. The first 184 pages are devoted to the record of the preparations for the meeting, the social meetings, list of members, minutes of proceedings, and reports of commissions. Pages 185 to 1286 contain the scientific memoirs (forty-six in number) read at the

meetings. Their titles, somewhat abbreviated, are as follows:—[1] J. G. Aguilera, on the Geology of Mexico,* and on the Volcanoes of Mexico*; three papers by Professor R. J. Anderson, on the Drift, Granite, and Metamorphic Rocks of Galway; a paper by Dr. Tempest Anderson on the West Indian Eruptions, and another on the Eruption of Vesuvius; H. F. Bain, on Ore Deposition in the Mississippi Valley; Professor F. Becke, on Crystallization Schistosity and Piezocrystallization†; Professor W. Branca, on Volcanoes and Fissures†; Professor S. Calderon, on Contact Phenomena‡; Professor L. Cayeux, The Structure of Sandstones and Quartzites,* Insect Eggs of Lakes Chalco and Texcoco and the Formation of Oolites*; Professor A. P. Coleman, Interglacial Periods in Canada; Professor T. W. E. David, Glaciation in Lower Cambrian, possibly in Pre-Cambrian Time; Australasia, Climate at different geological epochs*; Climate at different Geological Epochs, with special reference to Glacial Epochs; Occurrence of Diamonds in Matrix near Inverrell, New South Wales; Professor G. De Lorenzo, The Bases of the Volcanoes Vulture and Etna§; Professor S. Diaz, Diary of the behaviour of the Volcano of Colima, 1893 to 1905‡; Professor F. Frech, on Climatal Changes of the Geologic Past†; Aviculidæ of Palæozoic habit from the Trias of Zacatecas†; Professor J. W. Gregory, Climatic Variations, their Extent and Causes; Professor U. Grubenmann, The Classification of the Crystalline Schists†; Professor Heilprin, Interrelation of Volcanic and Seismic Phenomena; Professor E. W. Hilgard, The Causes of the Glacial Epoch; Dr. E. O. Hovey, The Western Sierra Madre of the State of Chihuahua*; B. de Inkey, The Relation between the Propylitic state of Andesitic Rocks and their Mineral Veins*; Dr. K. Keilhack, The occurrence of Onyx at Etla†; Professor J. F. Kemp, Ore Deposits at the Contacts of Intrusive Rocks and Limestones; Professor J. Koenigsberger, on the Influence of Mountains, Lakes, etc., on the Geothermal Gradient†; Dr. G. F. Kunz, Gems and Precious Stones of Mexico; General L. de Lamothe, The Climate of North Africa in the Upper Pliocene and the Pleistocene*; Professor L. de Launay, The Genesis of the Metals of Italy*; Notes on Mines in Tuscany and Elba; W. Lindgren, The Relation of Ore Deposits to Physical Conditions; Dr. M. Manson, Climates of Past Geologic Epochs and their Cause*; Professor S. Meunier, A Theory of Volcanic Phenomena*; Professor A. G. Nathorst, Upper Jurassic Flora of Hope Bay, Graham Land; T. Ogawa, The Geotectonic of the Japanese Islands; Dr. C. Renz, The Older Mesozoic Rocks of Greece†; V. Sabatini, The last Eruption of Vesuvius*; Professor G. Stefanescu, *Dinotherium gigantissimum**; J. D. Villarello, on the infilling of certain Metalliferous Deposits*; Bailey Willis, The Geological Map of North America*. The brief account of the excursions made in connection with the Congress occupies pages 1289 to 1350, and a table of contents is given at the end of the second volume.

B. Hobson.

[1] Memoirs in English except those marked * in French, † in German, ‡ in Spanish, § in Italian.

REVIEWS.

I.—Geological Survey of Canada. A. P. Low, Deputy Head and Director. Report on the Geology and Natural Resources of the Area included in the North-West Quarter-Sheet, No. 122, of the Ontario and Quebec Series, comprising Portions of the Counties of Pontiac, Carleton, and Renfrew. By R. W. Ells. [With a Palæontological Appendix, by H. M. Ami.] 8vo; pp. 71, with map. Ottawa: S. E. Dawson, 1907.

THE area here described, the "Pembroke Sheet" of the map, lies to the west of No. 121, the "Grenville Sheet," and has an area of 3,456 square miles. Its eastern boundary is not far from the Gatineau river, north of Ottawa city, and its south-western portion is traversed by the Ottawa river from a point about thirty miles west of Pembroke to within ten miles of the city of Hull. The rock formations comprised in it are as follows:—

Palæozoic Formations.

Trenton Limestone.
Black River Limestone.
Chazy Limestone and Shales.
Calciferous Dolomite.
Potsdam Sandstone.

Crystalline Rocks, including:—

Granite and Granite-gneiss.
Gneiss, Quartzite, and Limestone of the Grenville Series.
Anorthosite and other Igneous Rocks.
Post-Pliocene Deposits.

The crystalline rocks, which fill the most important place in the area surveyed, comprise the so-called fundamental gneiss and associated granite, and the upper series of banded gneiss with quartzite and crystalline limestone, the latter having the greatest development in the eastern half of the area surveyed, the older series in the western. Here the limestone is generally absent, but when present it is in the form of narrow bands resting on well-bedded quartzose gneiss, which in some places, the Coulonge river, for instance, forms cliffs, in which it presents the bedded aspect of the Potsdam Sandstone.

The fundamental gneiss is well seen in the western part of the area, where it has, in some places, a well-defined gneissic structure, but the rock is often granitic. These rocks apparently represent the oldest known geological formation of the Ottawa district. In that portion of the gneiss associated with the quartzite and limestone in the area adjacent to the Gatineau river, deposits of mica, apatite, and graphite are numerous and valuable. The limestones generally occur in basins and represent the upper part of the Archæan rocks. They usually rest upon well-bedded masses of white quartzite.

In summing up the results of his investigation of these crystalline rocks Dr. Ells remarks that "from an examination of all the features of the problem it has now been generally accepted that the Laurentian should be confined as far as practicable to the fundamental granitic gneiss, that the rocks of the Grenville and Hastings series should be

regarded as a portion of the Huronian and represent the lowest members of that system in Eastern Ontario and in Quebec adjoining, and that the upper part of the Huronian is represented by the more schistose portion seen in the area farther south and west. In this manner much of the difficulty hitherto experienced in interpreting satisfactorily the great problem of the crystalline rocks disappears."

The Palæozoic rocks extend, according to the map, from the Potsdam Sandstone to the Trenton, both inclusive, but in the text they are said to range from the Calciferous to the Trenton Limestone. They form the remnant of the western margin of the great Ottawa basin, and are found at intervals along the Ottawa river, and also as scattered outliers in some of the neighbouring townships. They occur also on the north shore of the river near Ottawa city, as well as in places on the south shore.

Large collections of fossils were made, chiefly from the Black River Formation, lists of which are given.

The chief features in the surface geology of the district are large areas of clays, sands, and gravels, some of which show their marine origin by their containing the remains of fishes, etc.

The economic minerals do not appear to be of much importance, with the exception, perhaps, of iron and mica.

In the Appendix to the report (pp. 49–71) Dr. H. M. Ami gives preliminary lists of fossils from the Chazy, Black River, Trenton, and Pleistocene Formations. The best collections from within the area are those from the Black River Formation. The lists include the names of species long familiar to workers in the field of North American palæontology. They will prove an invaluable index to the interpretation of the age of the rocks in which they may be found wherever stratigraphical data might, without confirmatory evidence, be unconvincing. A map coloured geologically and on a scale of 4 miles to 1 inch accompanies the report.

A. H. F.

II.—Palæocene Strata in Denmark, near Copenhagen. By Karl A. Grönwall and Paul Harder.

Palæocæn ved Rugaard i Jydland og dets Fauna; af Karl A. Grönwall og Poul Harder. Danmarks geologiske Undersögelse, II Raekke, Nr. 18. 1907.

EXPOSURES of Palæocene strata are scarce in Denmark, but by a careful study of the fossils from the neighbourhood of Copenhagen considerable additions have been made to our knowledge of the Palæocene fauna. These strata belong, the authors think, to a zone older than that of the Thanet Sand, and tending to fill up the gap between Cretaceous and Tertiary. A considerable number of new species are figured and described; the rest are mainly referred to forms already known in North Germany. The deposit yielding these fossils is a glauconitic sand, with a conglomeratic base containing derivative Cretaceous fossils. The Cretaceous rock below is Senonian, the higher Cretaceous zones being there absent.

The authors consider that towards the close of the Cretaceous period a general rise of the land took place in northern Europe, the Danian being deposited in the south and west part of the Baltic. At the beginning of the Palæocene epoch they think that this sea of the North German plain entered into free communication with the sea over South Russia, which spread to meet it from south-east towards the north-west and north. Still later the western ocean overspread the Anglo-Parisian basin, thus entering into communication with the Eocene sea of the West Baltic and North Germany. During the same epoch rises of land towards the east completely severed the communication between the sea of South Russia and that of the West Baltic.

The Palæocene fauna described in this memoir is very different from that of the Thanet Sand, and is probably older. It is not clear why the authors consider that this Palæocene sea and the Danian sea did not extend across Britain. The fauna of the Trimingham Chalk shows us that the absence of the higher zones over most of Britain is only due to denudation. Why should not the same cause account for the absence of the earliest Eocene deposits?

C. R.

III.—Mexican Ammonites.

THE Instituto Geólogico de México has recently published Boletin Número 23 (dated 1906), "La Faune Jurassique de Mazapil, avec un appendice sur les fossiles du Crétacique Inférieur, par le Dr. Carlos Burckhardt" (13 by 9¼ inches), in 2 parts, text 216 pages, 43 plates.

Fifty-nine species of Ammonites are described from beds of Kimeridgian age, including *Oppelia flexuosacostata*, Qust., *Aspidoceras contemporaneum*, E. Favre, *Aspidoceras bispinosum*, Qust., sp., *Idoceras* (*Perisphinctes*) *laxevolutum*, Font., sp., *Idoceras Balderum*, Oppel, sp., *Haploceras Fialar*, Oppel, sp., *Aspidoceras acellanoides*, Uhlig. Twenty-six species of Ammonites are described from beds of Portlandian age, including *Phylloceras apenninicum*, Canavari, *Perisphinctes Nikitini*, Michalski, *Aspidoceras cyclotum*, Steuer. Forty-six new Jurassic (Kimeridgian or Portlandian) species are described, and eleven species of Ammonites from the Lower Cretaceous. The plates from photographs have been beautifully executed by Werner & Winter, of Frankfort o/M.

B. H.

IV.—Summary of Progress of the Geological Survey of Great Britain and of the Museum of Practical Geology for 1907. pp. iv, 175, with 1 plate and 8 text-illustrations. London: printed for H.M. Stationery Office, 1908. Price 1*s*.

WE have received from the Board of Agriculture and Fisheries the above-mentioned memoir of the Geological Survey, which has been issued somewhat earlier than was the case with the volume for the previous year. It contains, as usual, particulars of the field-work carried on in different parts of England, Wales, and Scotland.

In two districts of England the Survey has been occupied. (1) In Cornwall, where the eruptive rocks of the Lizard have engaged special

attention; elsewhere work has been carried on in the country about Padstow, Wadebridge, Callington, Camelford, and Bodmin Moor, and we have notes on the Delabole slates and other Devonian rocks, on the Devonian and Carboniferous rocks near Callington, and on the granite of Bodmin Moor, the rock-platforms and their relation to stream-tin deposits. (2) In the Midland district the Survey has been occupied at Matlock, Alfreton, Mansfield, and Ollerton, including parts of Sherwood Forest and the Trent Valley. The zones in the Carboniferous Limestone, the Coal-measures, Permian, Trias, Lias, and Drift deposits receive due attention.

In Wales the survey of the western end of the South Wales Coalfield has been continued in a complex area, where igneous rocks possibly of pre-Cambrian age, and Cambrian, Ordovician, Silurian, Old Red Sandstone, and Carboniferous rocks are developed. We note (on p. 39) that the Llandilo Flags are, by mistake, grouped with the Arenig. The disturbances in the Carboniferous rocks are specially mentioned.

In Scotland field-work has been carried on in the northern and western Highlands, in Caithness, the valley of the Findhorn, near Ben Nevis, and in the islands of Mull and Colonsay. Various schistose rocks, Torridon sandstone, Jurassic strata and Drifts, as well as igneous rocks, are dealt with. The Survey has also been occupied in the central portion of the Scottish coalfields.

The Appendix contains articles on the Mugearites, one of the Tertiary igneous rocks of the Inner Hebrides (illustrated by plate); on the Marine beds near the base of the Upper Carboniferous in Scotland, on the eastern extension of the Nottinghamshire and Yorkshire Coalfields, accounts of sections opened up on new branches of the Great Western Railway in Oxfordshire and Somerset, notes on the dates of some of the earlier published Geological Survey Maps, and a list of manuscript maps and sections in the Library of the Museum of Practical Geology.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

June 17th, 1908.—Professor W. J. Sollas, LL.D., Sc.D., F.R.S., President, in the Chair.

The following communications were read:—

1. "The Hornblendic Rocks of Glendalough and Greystones (Co. Wicklow)." By J. Allan Thomson, B.A., B.Sc., F.G.S.

Both these rocks are intrusive into Ordovician strata in the east of County Wicklow: the former occurring as a small boss in the south side of Camaderry, a ridge which separates the Vale of Glendalough from the valley of Glendrosan; while the latter occur as three dykes traversing the sedimentary rocks on the shore at Greystones. The Glendalough rock is older than the Great Wicklow Granite, and exhibits much heterogeneity in composition. The chief varieties are the following:—(1) A hornblende-peridotite, made up mainly of

amphibole with apatite, magnetite, pyrite, olivine, augite, chlorite, and calcite; an analysis of this variety is given; (2) amphibolite, with larger hornblende crystals separated by fine-grained amphibole; (3) actinolite rock, mainly made up of actinolite, but bearing also zoisite, sphene, and sulphides; (4) zoisite-amphibolite, made up of pœcilitic hornblende enclosed in a granular matrix which is white with zoisite; and (5) 'quartz-mica diorite,' containing quartz and felspar. The last variety is conceived to be a mixed rock, formed by the absorption of the amphibolite by an acid magma; an analysis of one of the most acid types is given. The Ordovician sediments are converted into hornfels at the contact with the igneous rock, and this type of rock has resisted the dynamic metamorphism which occurs elsewhere in the district. The Greystones rock shows a transformation from peridotite into amphibolite, but with a greater development of talc. Olivine and rarely mica are present in the original rock.

2. "On the occurrence of Footprints in the Lower Sandstones of the Exeter district." By Principal Arthur William Clayden, M.A., F.G.S.

Suitable exposures in the 'Lower Sandstones' of the Geological Survey map are very rare. Dr. Shapter has recorded 'claw-like footmarks,' etc., from a locality about half a mile north-east of Broadclyst. Another quarry has been recently reopened here for building stone; and, on a search being made, slabs with footprints were found by the author and his students. Later, a slab with a track containing thirty pairs of footprints was found. In all, five specimens have been secured; and three of the sets of prints may have been made by the same individual, one with fore and hind feet about the same size and bearing about the same weight. The two other sets of prints were made by smaller and different individuals. In one case the prints of the manus are slight, and those of the pes heavy, although the hind and fore feet were of about the same size. There is no trace of the tail being dragged. In the other the animal had all the characters of the last, except that the digits 5 and 2 were nearly equal. This track also shows that the animal sometimes threw nearly all its weight on the right side and sometimes on the left. In no case is there anything to suggest either claws, a sole to the foot, or a fifth digit. They are least unlike Cheirotheroid prints, but differ from them in the absence of a divergent digit. The specimens have been presented to the Exeter Museum.

3. "The Basic Intrusion of Bartestree, near Hereford." By Professor Sidney Hugh Reynolds, M.A., F.G.S.

The Bartestree dyke, which has a thickness of about 35 feet, strikes in an east-north-easterly direction through the Old Red Marls and Sandstones, which for a distance of at least 10 feet from the contact are strongly metamorphosed, the marl being converted into a hard purplish-grey rock with yellow patches, while in the sandstone the felspars are recrystallized and the quartz grains corroded.

The dyke itself is not a single uniform intrusion, but a multiple dyke composed of several allied though differing types of dolerite and

basalt. While the major portion consists of basalt, the marginal portion is chiefly doleritic. Dolerite and basalt are, however, intimately intermingled, patches of basalt occurring in the predominantly doleritic portion and *vice versâ*. The relations are clearly such as to point to the invasion of an earlier doleritic intrusion by a later one of basalt. Two types of dolerite further occur, a teschenite with fresh analcime and abundant augite and serpentinized olivine being the prevalent type. This closely resembles the Clee Hill rock, and it may be suggested with some probability that the Bartestree dyke is of the same age as the Clee Hill intrusion. The basalt in places shows patches with an imperfect variolitic structure.

ADMISSION OF WOMEN TO FELLOWSHIP OR ASSOCIATESHIP IN THE GEOLOGICAL SOCIETY OF LONDON.

A Special General Meeting was held before the Ordinary Meeting on Wednesday, June 17th, at 7.45 p.m., in order to consider the following resolution, proposed by Dr. J. Malcolm Maclaren and seconded by Mr. A. Gibb Maitland:—

> "That Fellows non-resident in the United Kingdom be invited to express an opinion concerning the Admission of Women to Fellowship or Associateship of the Geological Society of London."

This resolution was passed by 30 votes to 11.

The next Ordinary Meeting of the Society will be held on Wednesday, November 4th, 1908.

II.—MINERALOGICAL SOCIETY.—*June 16th*, 1908. Professor H. A. Miers, F.R.S., President, in the Chair.

On a nickel-iron alloy (Fe_2Ni_3) common to the meteoric iron of Youndegin and the meteoric stone of Zomba, by L. Fletcher. In the case of the Zomba meteoric stone the gradual increase of nickel in the residue after repeated extraction of the nickel-iron with mercuric ammonium chloride was previously attributed to rusting. It is now explained by the presence in the nickel-iron of a component not easily affected by the mercuric solution, and containing 38·50 per cent. of nickel. This component is identical with the 'tænite,' containing about the same percentage of nickel, which was separated from the Youndegin iron by its insolubility in dilute hydrochloric acid.—On Kaolinization and other changes in West of England rocks, by F. H. Butler. The author pointed out that the gaseous emanations of a granitic magma, which are carried upwards and discharged externally, gradually bring about considerable pneumatolytic changes. Notable among these are increased vesicularity in the quartz of the peripheral part of granitic intrusions and their offsets, the elvans, also the assumption by that mineral of the idiomorphic form, and the production of tourmaline. The occurrence of tourmaline in rocks exemplifying various stages in metasomatism indicates long-continued supply of boron compounds from abysmal regions. The primary, usually brown, tourmaline in the altered acidic rocks is commonly found to have been eroded, doubtless owing to alkalinity of the kaolinizing solution, before dekaolinization and the consequent formation of acicular schorl ushered in a final deposition of quartz. The view of Professor Vogt

and other authorities that kaolinization was effected by the rise of solutions of carbon dioxide from among calciferous rocks receives support from the occurrence of calcium sulphate in underground waters and of numerous calcium compounds in mineral veins and lodes. The unchanged condition of some topaziferous granite is one of various indications that the action of hydrofluoric acid on rocks has been low down rather superficial. It, or hydrofluosilicic acid, appears to have played a part in the following sequence of events in the West of England:—(1) Decomposition of deep-seated calcite-bearing rocks, and consequent kaolinization of neighbouring granite by evolved carbon dioxide. (2) Local and variable dekaolinization, fluorization, and tourmalinization of china-clay rock and china stone by borated waters carrying dissolved fluor-spar, resulting in the formation of schorlaceous rocks and greisen. (3) Lastly, supply to the metasomatized rocks of tin stone and wolfram from solution, and then of silica. The author concluded with a brief summary of facts subversive of the popular notion that the kaolin of commerce is the result of subaerial action upon granite. — On Schwartzembergite, and the drawing of light figures, by G. F. Herbert Smith. The author described the crystals occurring on three specimens in the British Museum, the locality being San Rafael, Chili. They are formed of four low pyramido-faces above and below, eight in all, with nearly square contour, the angle from the centre averaging 20° with range 15°–25°, and simulate tetragonal symmetry; steep pyramids are occasionally present also. The mean refraction is 2·350. The optical characters are remarkable: through each pyramid face appears in convergent light a biaxial interference-figure ($2E = 16°$) with negative birefringence, the axial plane being parallel to the edge of the contour; but through intermediate sectors appears another biaxial interference-figure with larger angle ($2E = 33°$), the axial plane being in this case radial; the number of different directions of single refraction in the crystal is, however, only four. The pyramids give, with pin-hole object, a continuous band of light. Since there was no well-defined image from which to measure, it was necessary to draw these figures direct on to a projection. The author described a camera-lucida attachment for the goniometer, which would allow of the preparation of projections of different sizes and of the relative variation required by the distortion in a projection. — The chemical composition of Seligmannite, by G. T. Prior. The results of two analyses show that this new mineral from the Binnenthal is a sulph-arsenite of copper and lead ($PbCuAsS_3$), corresponding to the sulph-antimonite, bournonite, with which it is crystallographically similar.

III.—Zoological Society of London.—*June 16th*, 1908. Dr. Henry Woodward, F.R.S., Vice-President, in the Chair.

Dr. A. Smith Woodward, F.R.S., F.Z.S., exhibited photographs and fragments of skin and bone of a Mammoth and a Rhinoceros discovered in an ozokerite mine at Starunia, Galicia. The carcases of these animals appeared to have found their way into an old marsh saturated with petroleum, which had completely preserved them.

The photographs and specimens had been received from Dr. George von Kaufmann, who intended to present them to the British Museum.

Dr. C. I. Forsyth Major, F.R.S., F.Z.S., exhibited the lower jaw of a young Canadian Beaver in which there was present on each side a small conical tooth anterior to the deciduous premolar. He considered the supernumerary premolar to be a case of atavism. He also exhibited a set of drawings made from examples of two species of *Castor* from the East Runton Forest-bed, and remarked that truly Forest-bed species were found in association with Pliocene species. He discussed incidentally the numerous species of recent European Beavers admitted by Professor Matschie. Lastly, he exhibited photographs of Pliocene *Bovinæ* from specimens in the Florence Museum, stating that these unpublished figures showed the great variability of the Pliocene *Bovinæ*. He added that he endorsed Falconer's opinion that these Pliocene *Bovinæ* were nearly related to the primitive Buffaloes from the Siwaliks.

OBITUARY.

HENRY CECIL MOORE,

PRESIDENT OF THE WOOLHOPE NATURALISTS' FIELD CLUB.

BORN 1835. DIED JUNE 21ST, 1908.

THERE are perhaps two main ways of forwarding scientific knowledge. The one is by contributing original work; the other is by instilling a liking for such work by means of personal energy and enthusiasm, and the publication and dissemination of popular resumés and interesting accounts of excursions made in the field. The former method is naturally essential, but the indirect support given the former by the latter is perhaps frequently lost sight of. Therefore it is fortunate indeed that there are men, imbued with energy and enthusiasm, and what is more important the property of imparting such, who arise from time to time to carry on this great work of popularization. Few there have been in the West Country and Borderland who have been more worthy of fame on this account than H. C. Moore, who died on Sunday, June 21st, 1908, while in office as President of the Woolhope Naturalists' Field Club.

Like the great geologist who trod Siluria long years before, Moore led with characteristic enthusiasm and energy his bands of Woolhope Club members over the hills and dales of Herefordshire and the adjacent counties on the west. Moore's early life was spent in the Army as a Royal Engineer. Son of Brigadier-General G. Moore, of the Bengal Army, he was born at Lucknow in 1835; was educated at Wem, Leamington College, and privately; and at the age of 18 entered Addiscombe College. At the end of two years there he became a lieutenant in the Royal Engineers, and was temporarily attached to Sir Hugh Rose's Field Force for the suppression of the Indian Mutiny. On March 17th, 1858, he arrived at Aden, and was present at the capture of the fortified village of Shaikh Othman on the following day. During parts of the years 1858 and 1859 he was Assistant Engineer, Public Works Department, Aden